A Multi-Sensor Perspective on the Interannual Variability of Tropical Temperature and Water Vapor

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Sun Wong

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Motivation

To better characterize the controls on the tropical upper tropospheric/lower stratospheric (UTLS) temperature and humidity.

Stratosphere

~50hPa

~100hPa

Tropopause

TTL

$Q_{clear}=0$

~200hPa

Cold

Warm

Troposphere

Warm
Moist
Upward Motion

Cool
Dry
Subsidence

~1000hPa

Warmer SST

Cooler SST

Tropical Western Pacific

Tropical Central Pacific

Stratosphere

~50hPa

~100hPa

~200hPa

~1000hPa

Quasi-Biennial Oscillation (QBO)
Baldwin, RG, 1999

Tropopause

Cold

Warm

TTL

$Q_{clear}=0$

Troposphere

Warm
Moist
Upward Motion

Cool
Dry
Subsidence

El Niño Southern Oscillation (ENSO)
Trenberth, AMS, 1997

Warmer SST

TWP

Cooler SST

TCP

Stratosphere

~50hPa

~100hPa

~200hPa

~1000hPa

Quasi-Biennial Oscillation (QBO)
Baldwin, RG, 1999

TTL *T* & H_2O

Tropopause

TTL

Q_{clear}=0

Cold

Warm

Warm
Moist
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Cool
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Subsidence

Troposphere

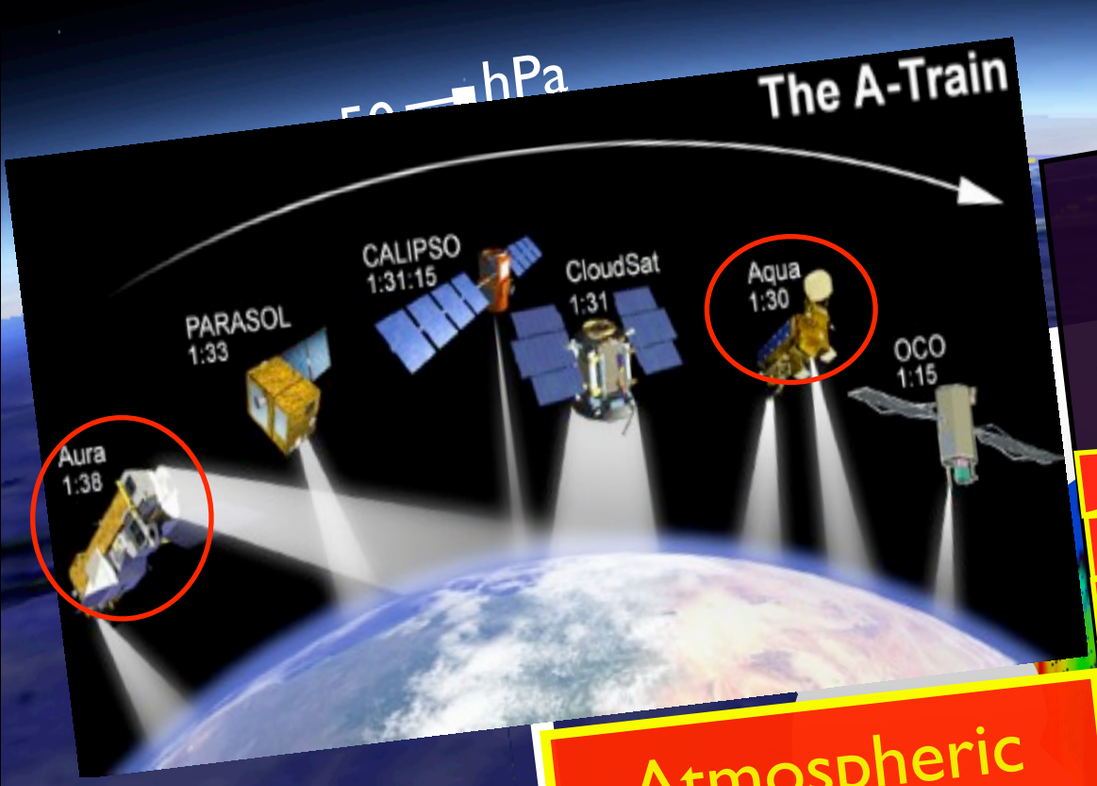
El Niño Southern Oscillation (ENSO)
Trenberth, AMS, 1997

Warmer SST

TWP

Cooler SST

TCP



hPa

500

1000

Atmospheric Infrared Sounder (AIRS)

AIRS ~1-3 km

MLS ~2 km

Microwave Limb Sounder (MLS)

~45 km

MLS (~200 km)

Datasets:

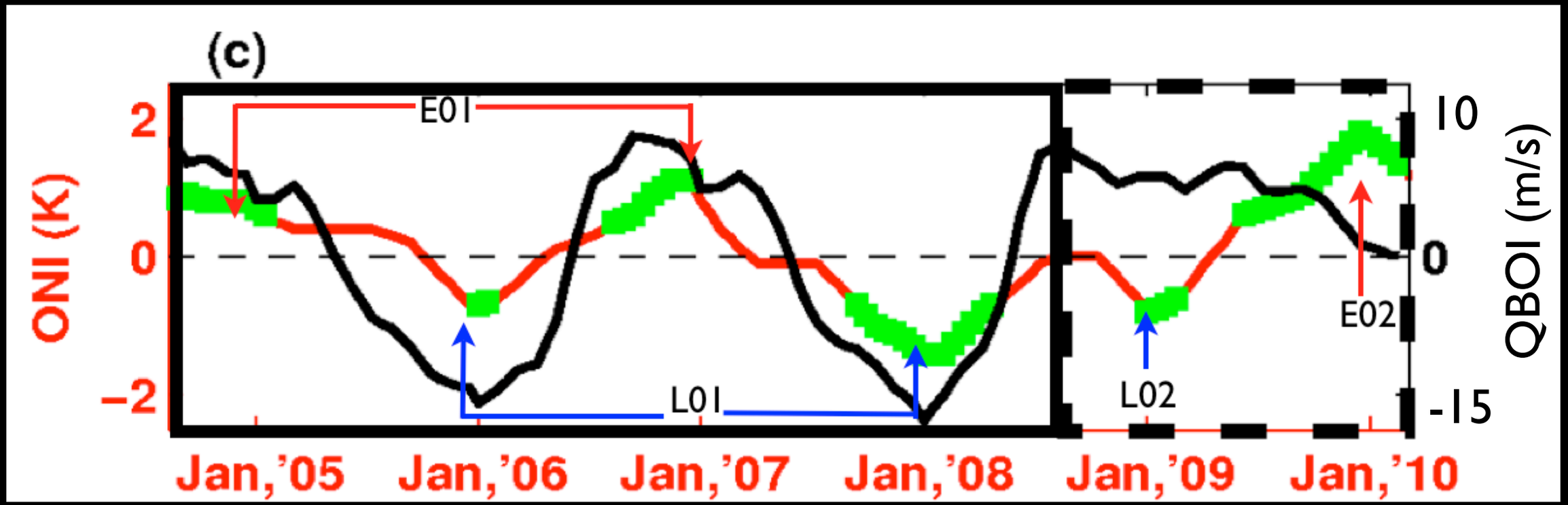
(1) Temperature (AIRS) (Accuracy ≤ ~0.5K)

(2) Combined H_2O (AIRS,MLS) (Liang, et.al, AMT (2010), manuscript in review)

(3) Lat: 8S-8N, Lon: 180E-180W

AIRS		MLS	
P (hPa)	Accuracy (%)	P (hPa)	Accuracy (%)
150	25	83	7
200	25	100	8
250	20	121	12
300	15	147	15
400	10	178	17
500	5	215	25

ENSO and QBO Indices



- Ocean Niño Index (ONI) in the Niño3.4 region (5S-5N, 120W-170W) *(Source: NOAA CPC, in-situ measurements)*

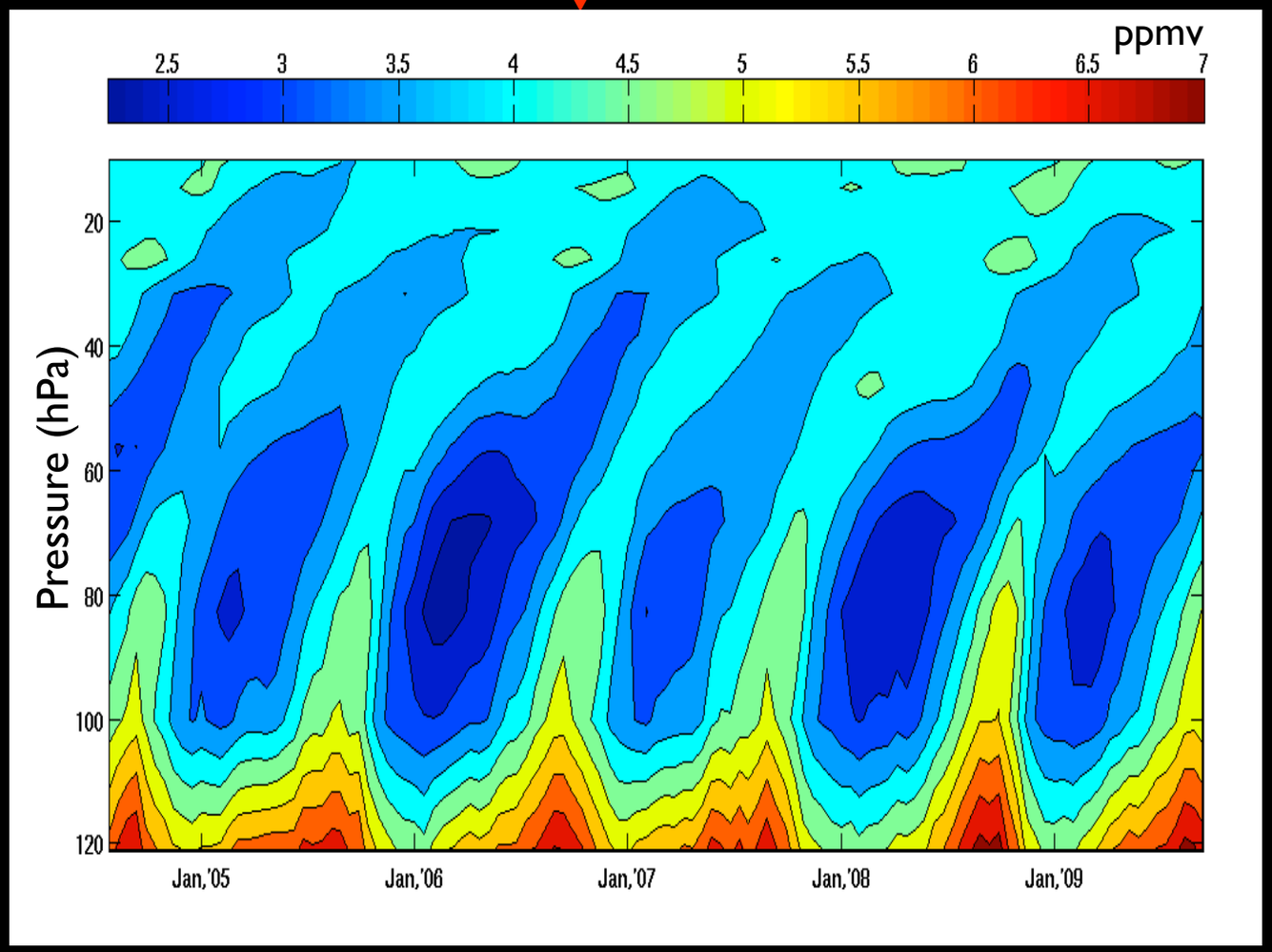
- QBOI represent zonal mean zonal wind anomalies at 50 hPa *(Source: NCAR/NCEP reanalysis)*. Anomalies in thermal wind balance with lower stratospheric temperatures *(Randel et.al, JGR, 2000)*

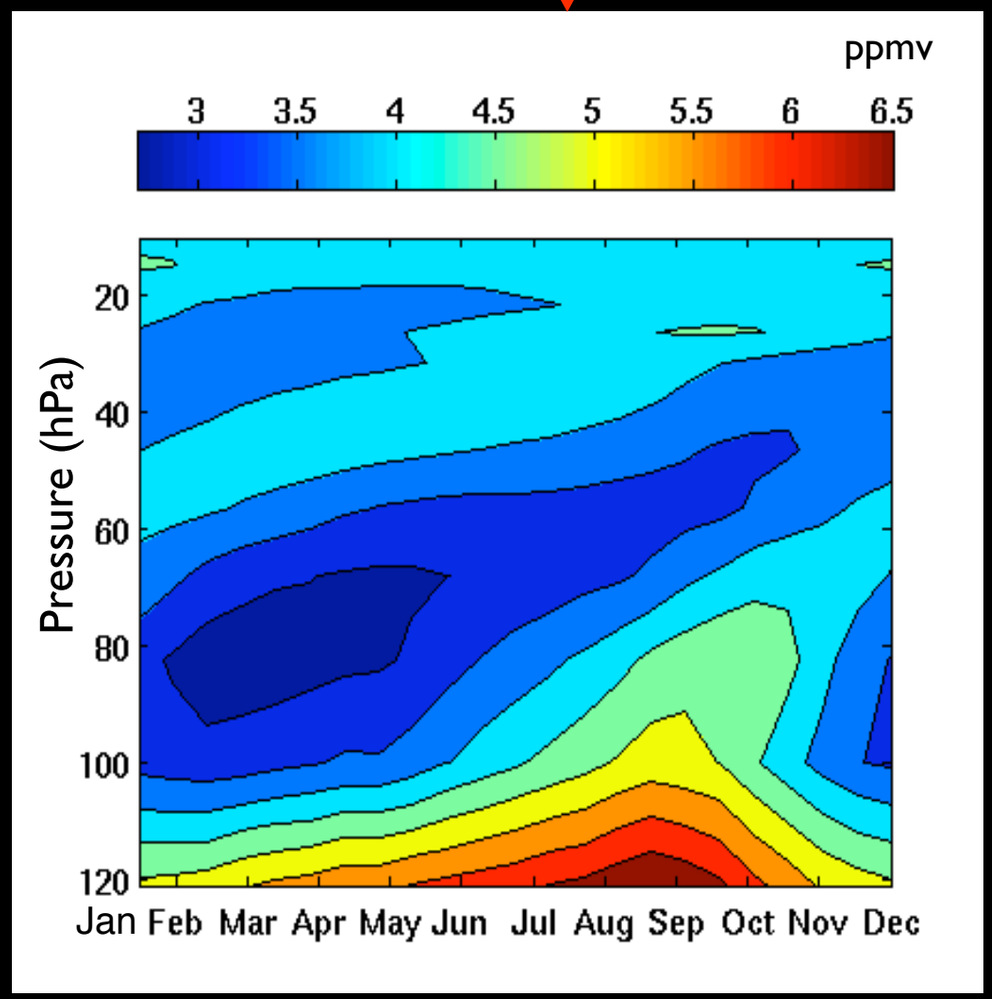
Seasonal and Annual Cycle of H_2O

AIRS/MLS Time Series

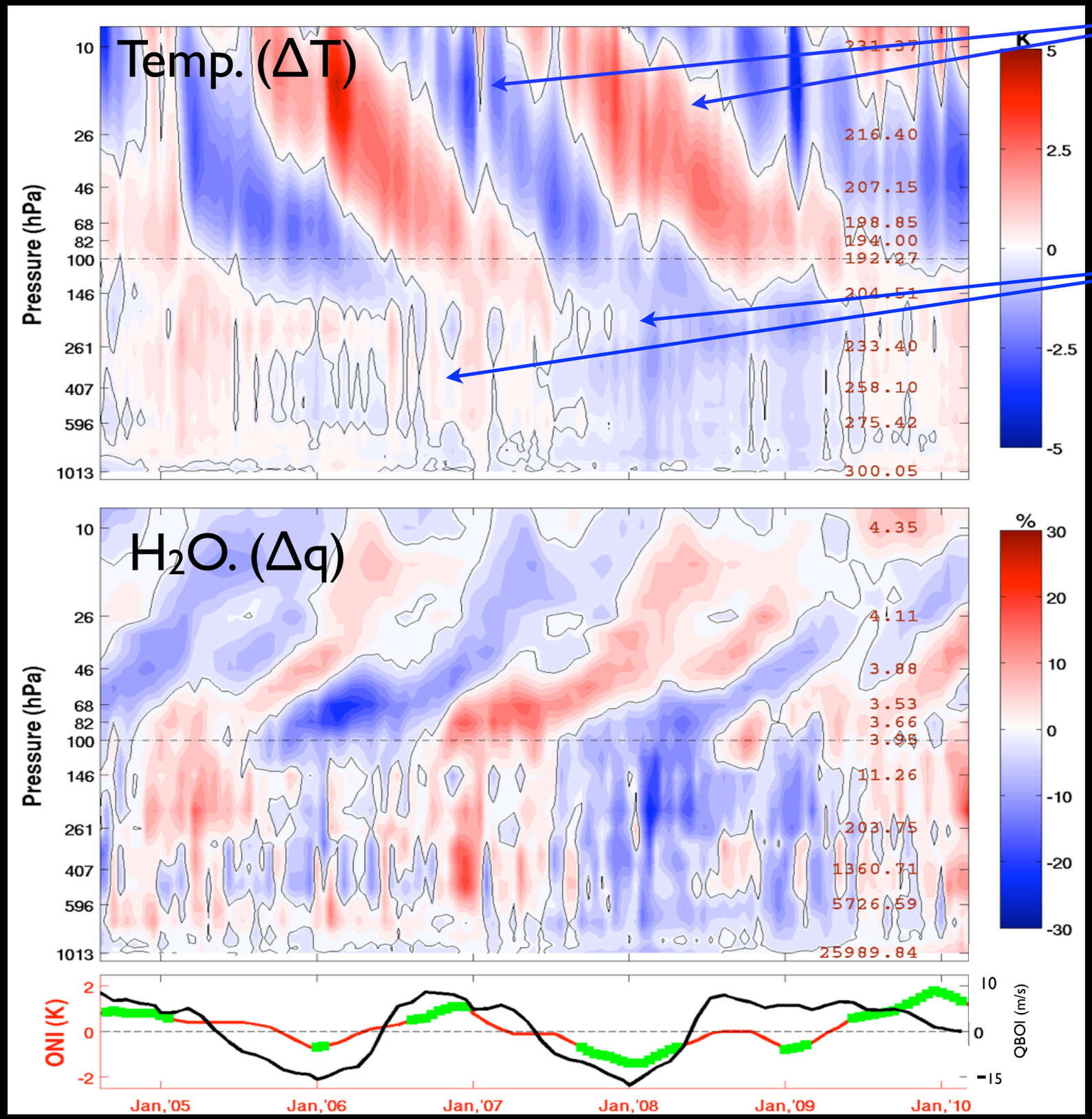
minus

Annual Cycle





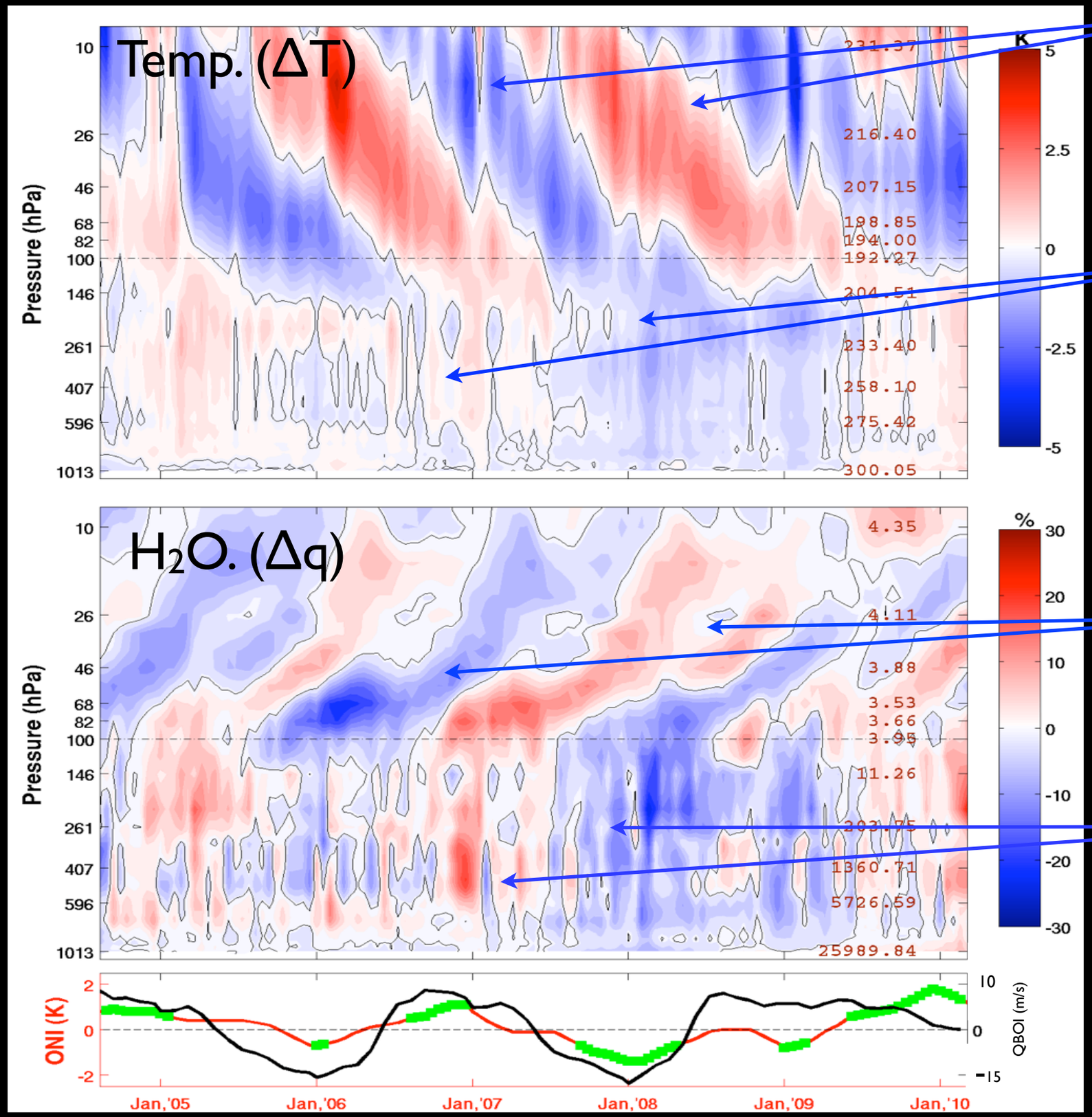
Surface to Stratosphere Interannual Variability of T and H_2O



Quasi-biennial Oscillation (QBO) for T with period ~28 months

ENSO

Surface to Stratosphere Interannual Variability of T and H_2O



Quasi-biennial Oscillation (QBO) for T with period ~28 months

ENSO

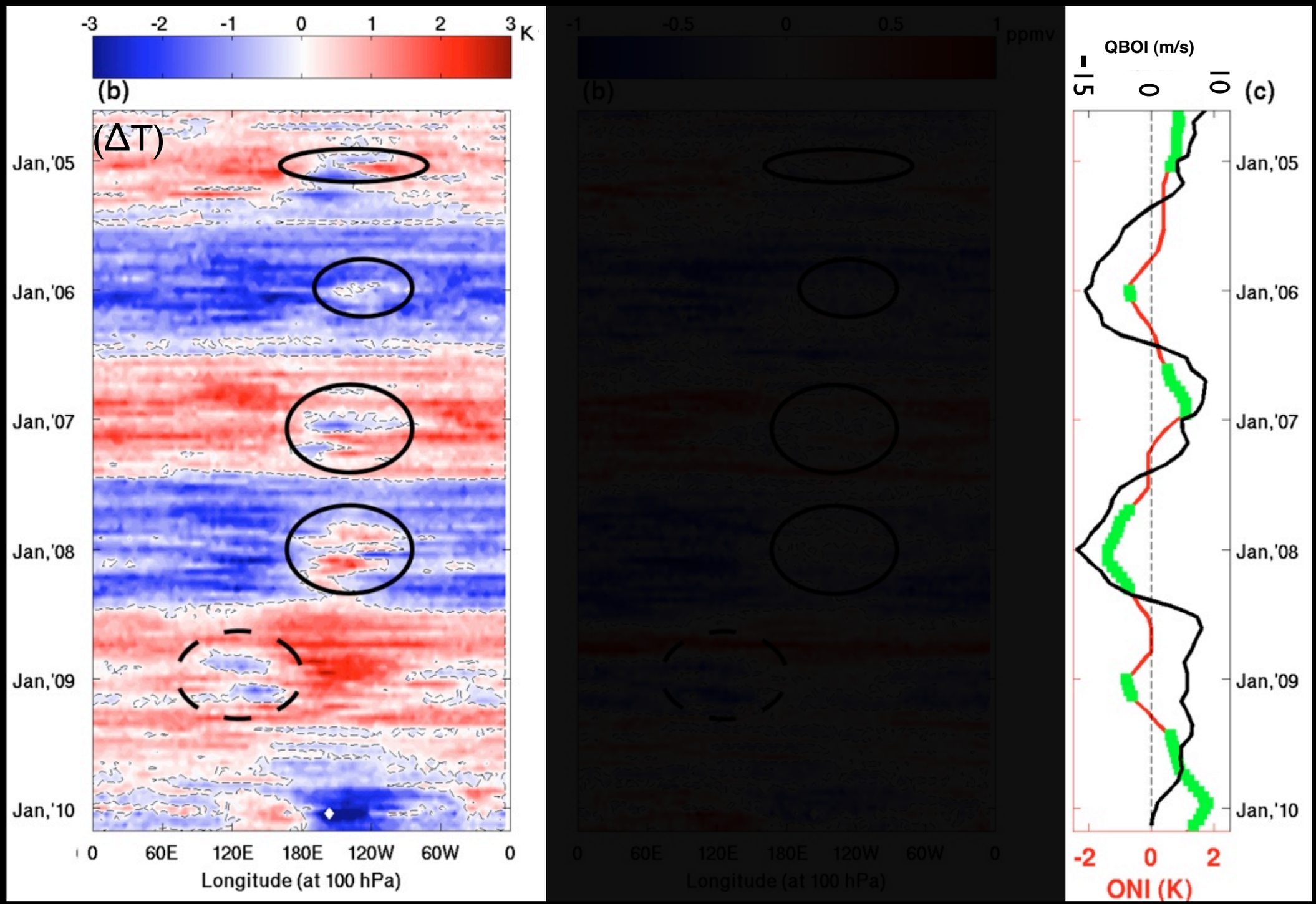
Interannual Variability of tape recorder

(Randel, et. al., JAS, 1998, Gellar, et. al., JAS, 2002)

ENSO

New vertical picture of H_2O

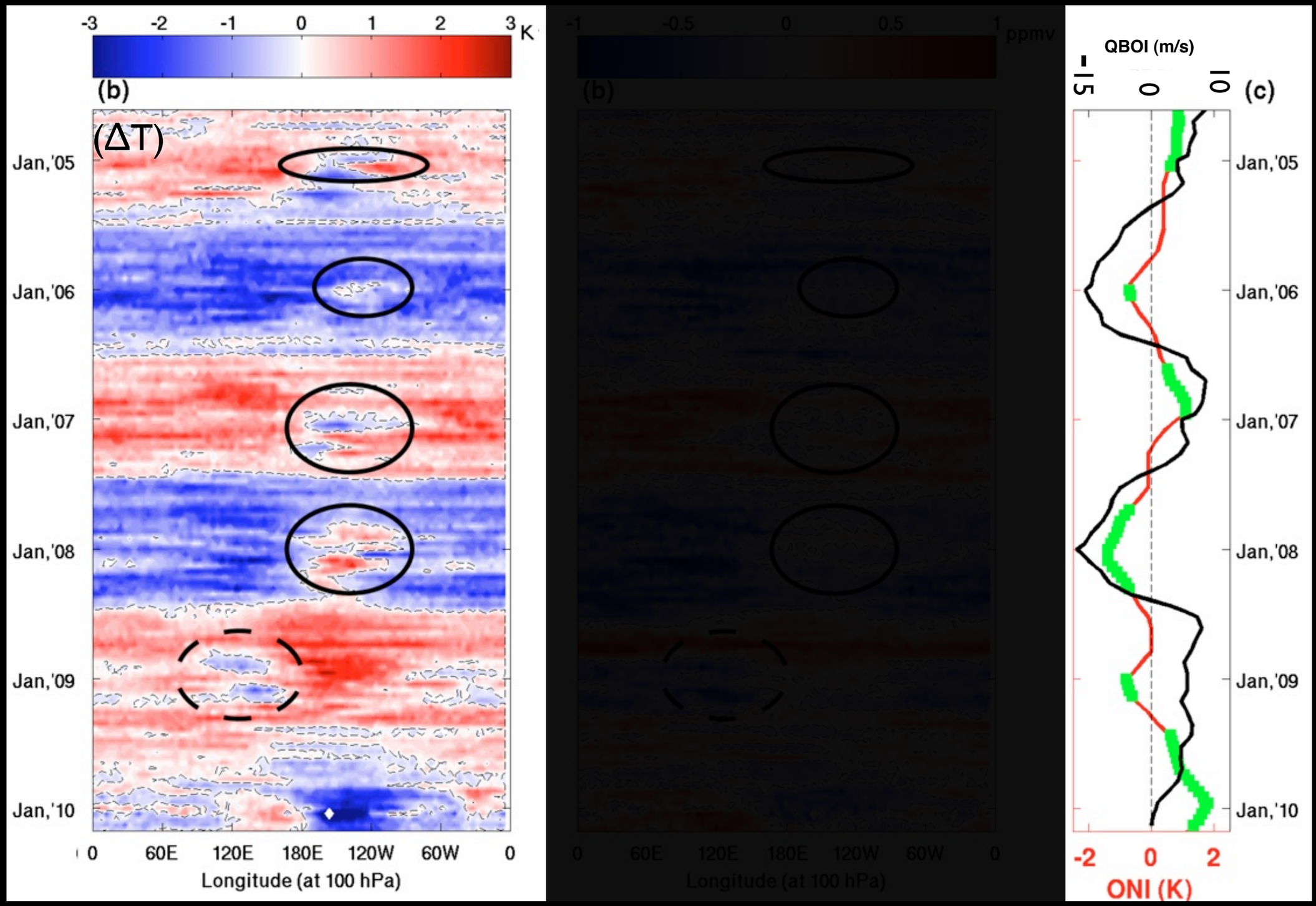
Zonal Structure of ΔT and Δq



Liang, et.al, JGR (2010), Manuscript in review

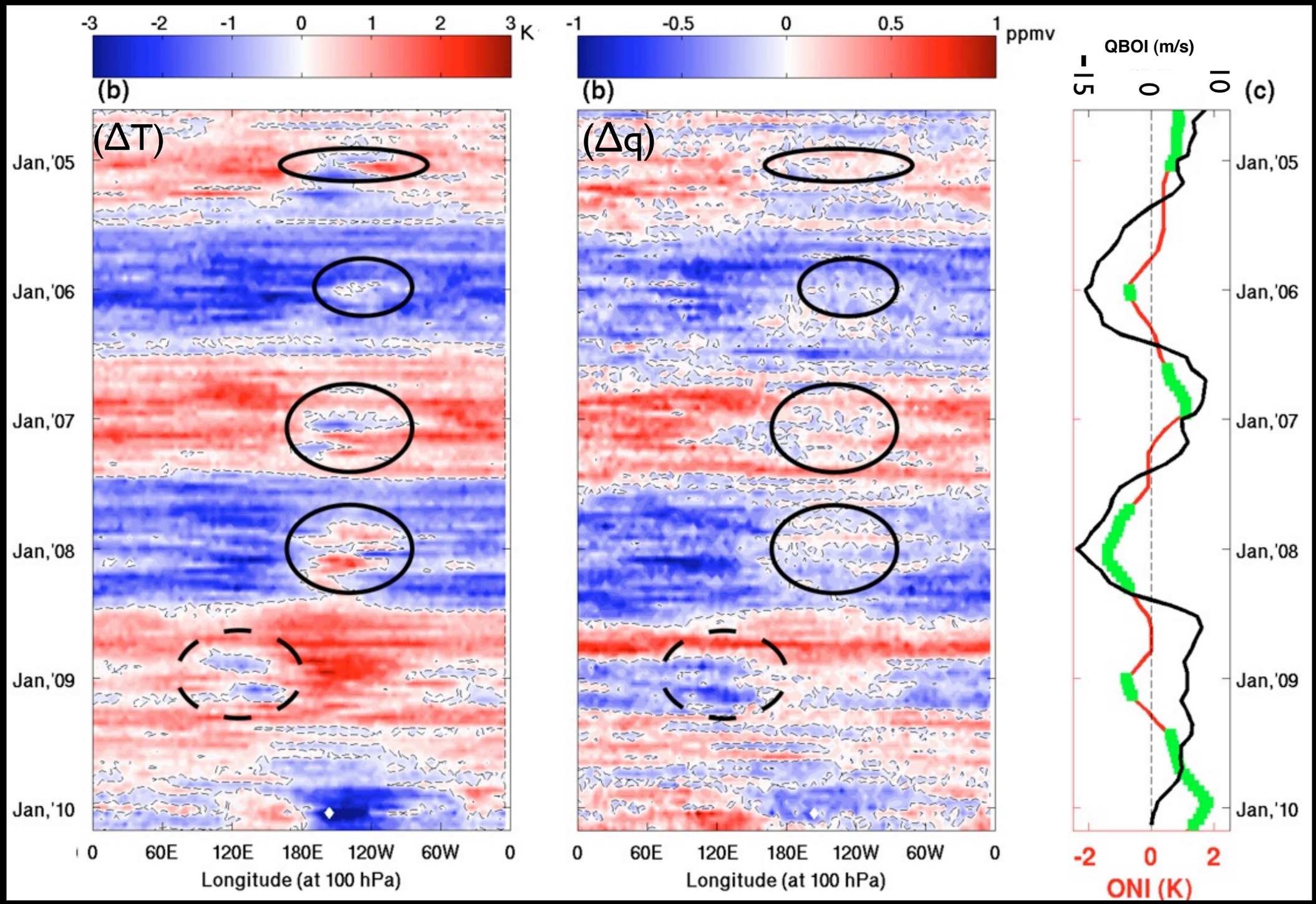
Zonal Structure of ΔT and Δq

Correlation between ΔT and QBO: R=0.86



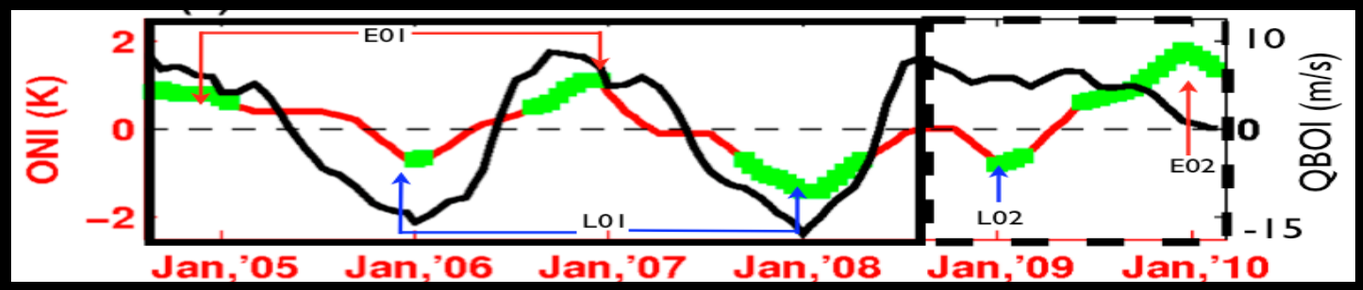
Liang, et.al, JGR (2010), Manuscript in review

ΔT and Δq mainly driven by QBO *(Randel, et.al, 1998)* but with some zonal asymmetries



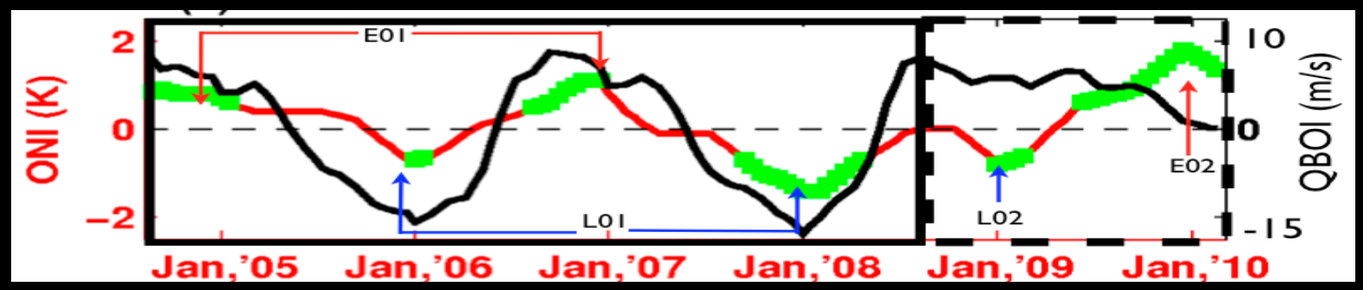
Liang, et.al, JGR (2010), Manuscript in review

Composites of ENSO events



ENSO Phase
E+ = El Niño
E- = La Niña

QBO Phase
Q+ = Westerly
Q- = Easterly



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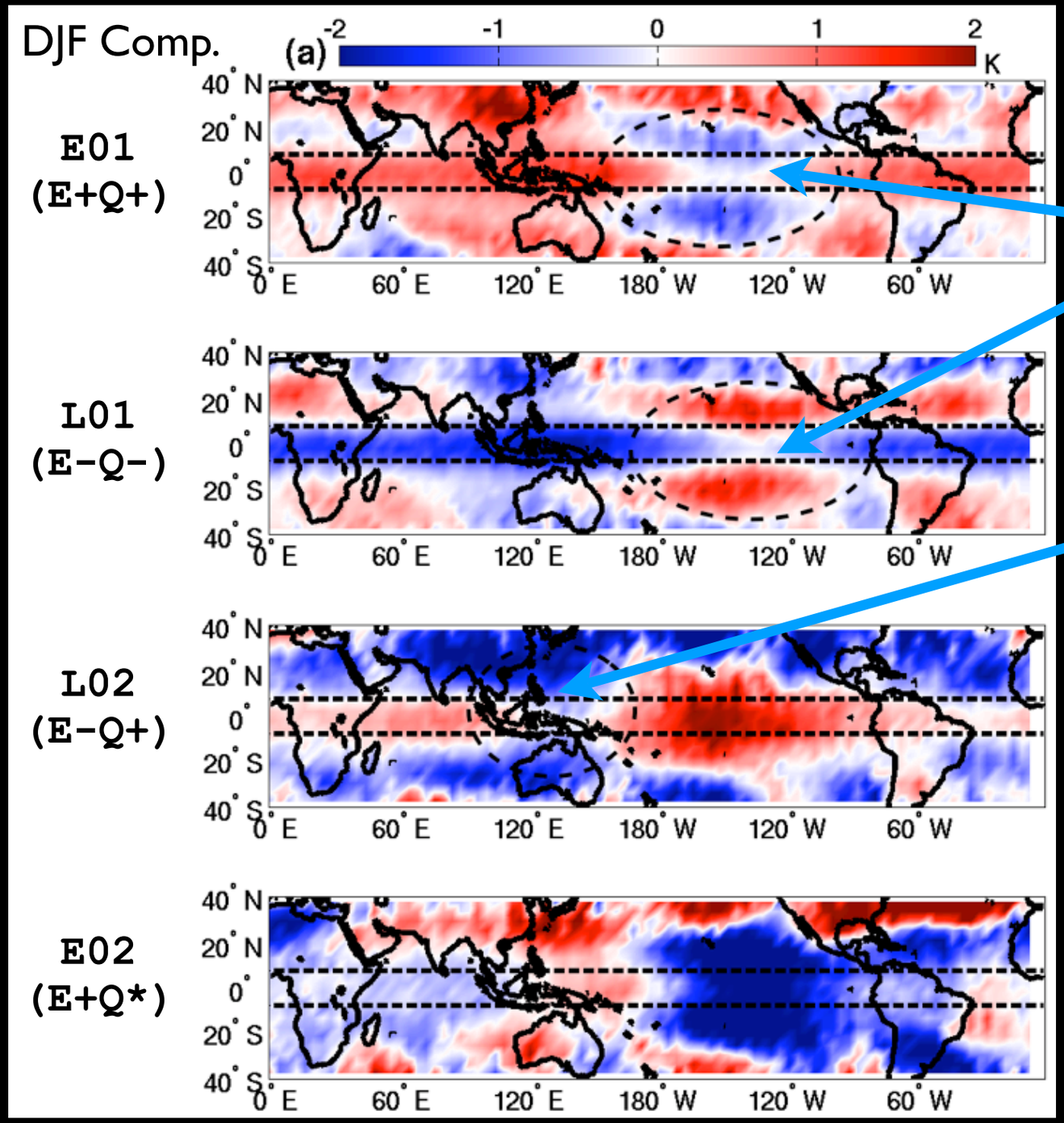
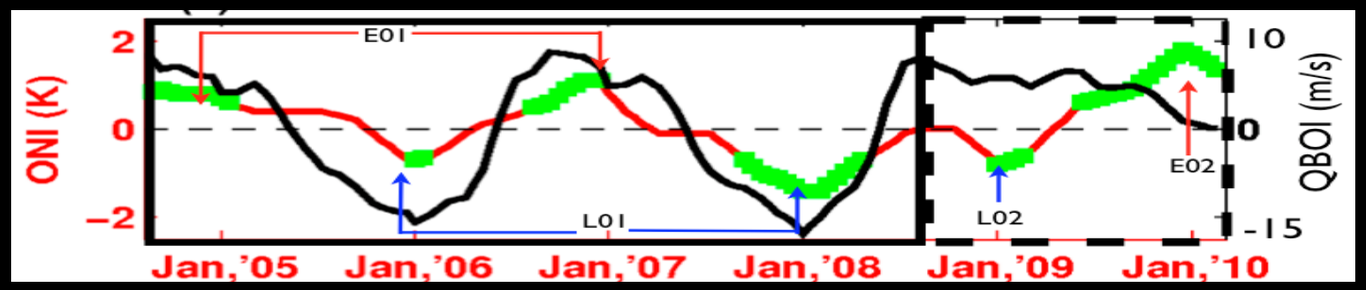
ΔT (100 hPa)

DJF Comp.



- Zonal break over TCP when QBO and ENSO in phase
- TWP experiences zonal break when ENSO and QBO out of phase

Liang, et.al, JGR (2010), Manuscript in review



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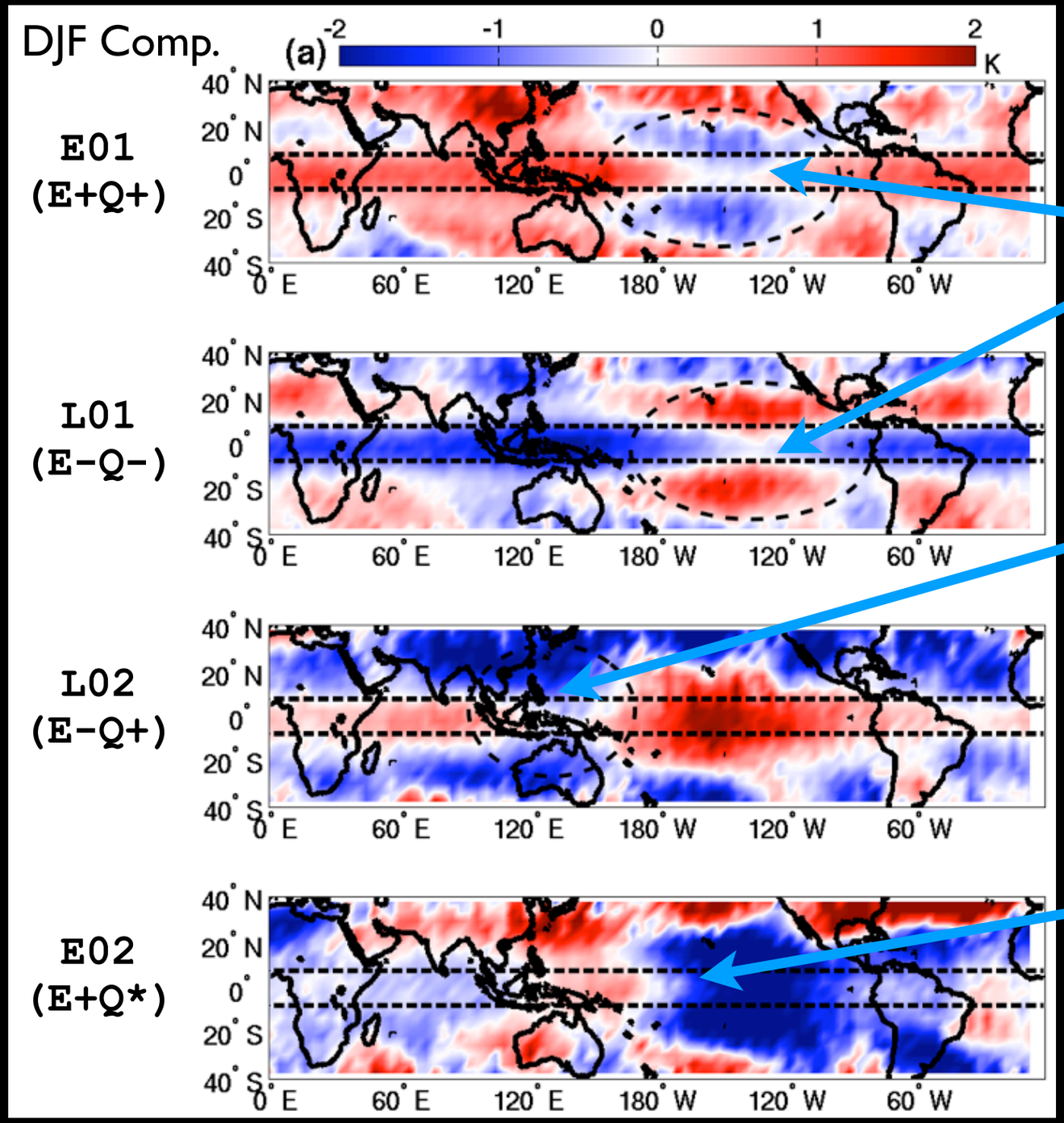
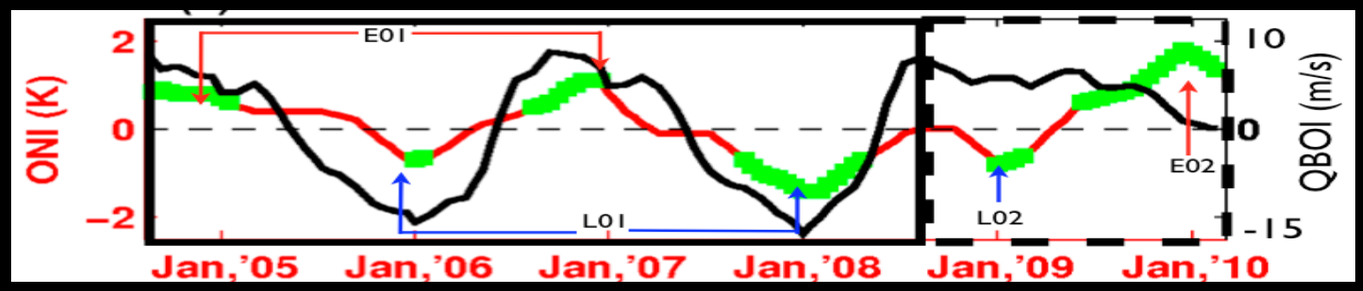


- Zonal break over TCP when QBO and ENSO in phase
- TWP experiences zonal break when ENSO and QBO out of phase
- E02 event primarily an ENSO signal; QBO in transition

Liang, et.al, JGR (2010), Manuscript in review



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ΔT (100 hPa)

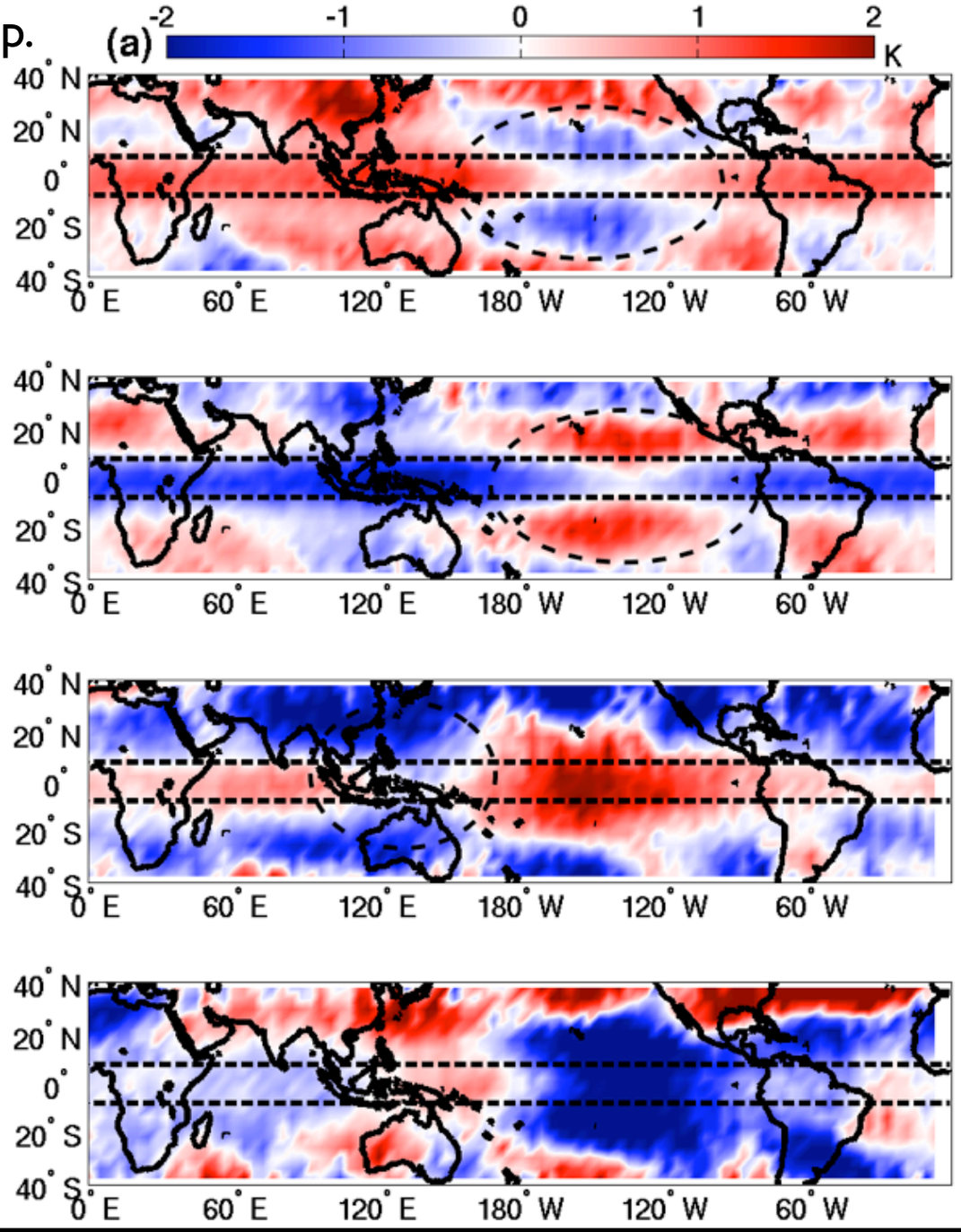
DJF Comp.

E01 (E+Q+)

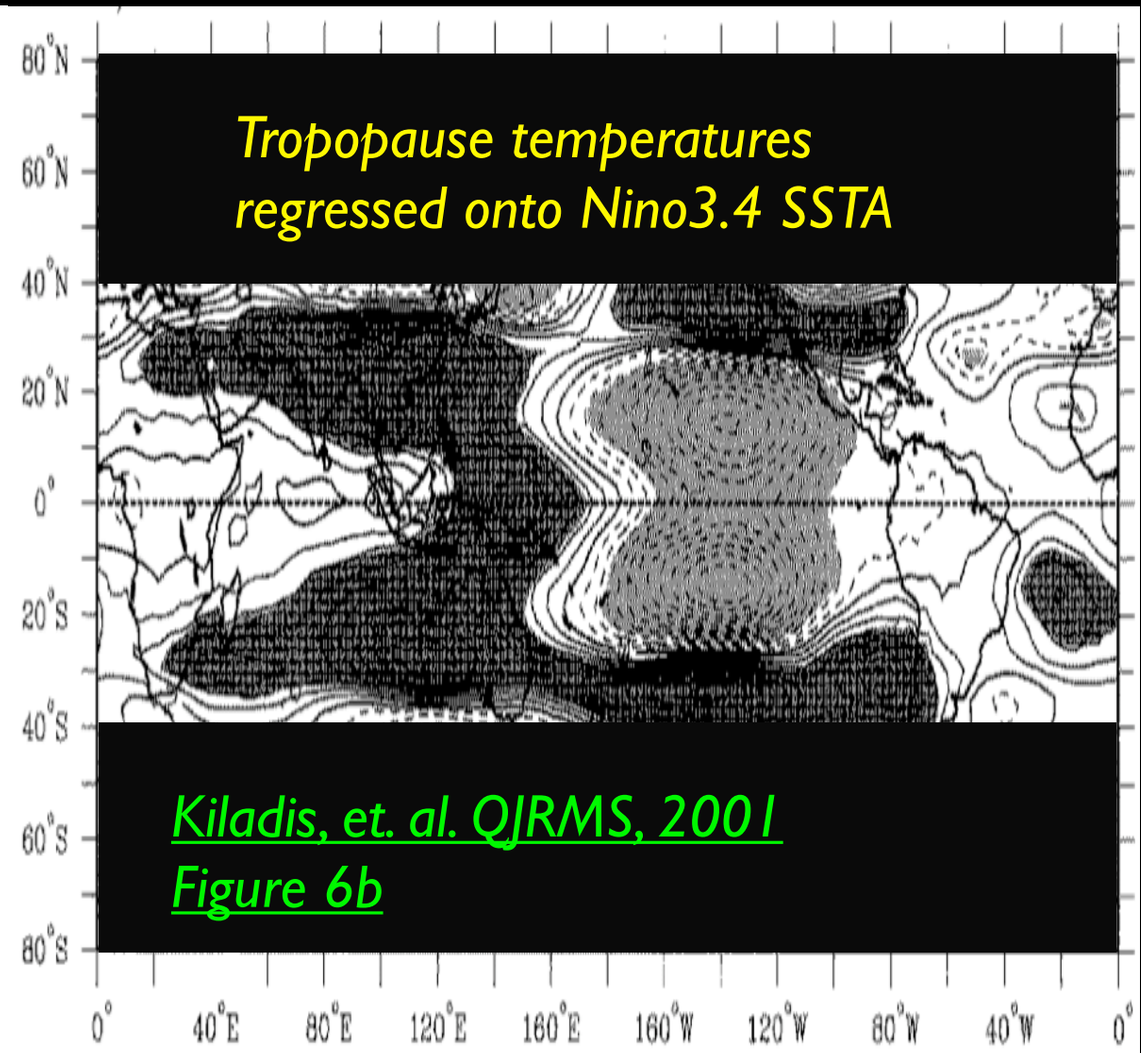
L01 (E-Q-)

L02 (E-Q+)

E02 (E+Q*)

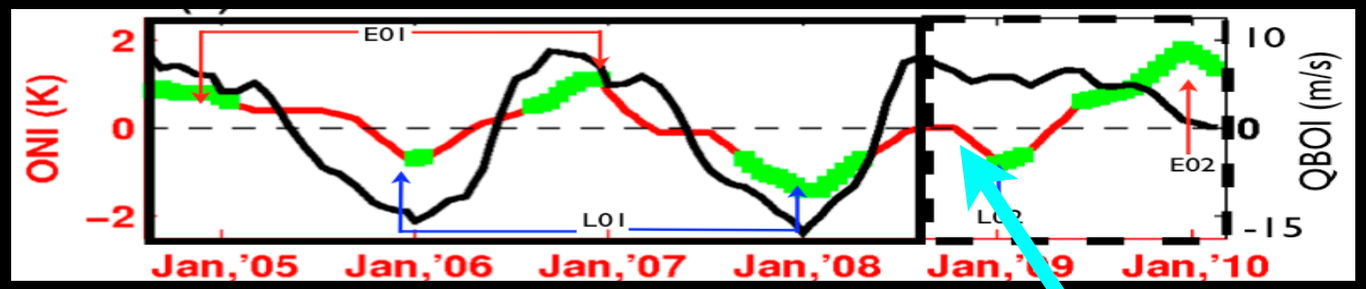


Tropopause temperatures regressed onto Nino3.4 SSTA



Kiladis, et. al. QJRMS, 2001
Figure 6b

Liang, et.al, JGR (2010), Manuscript in review



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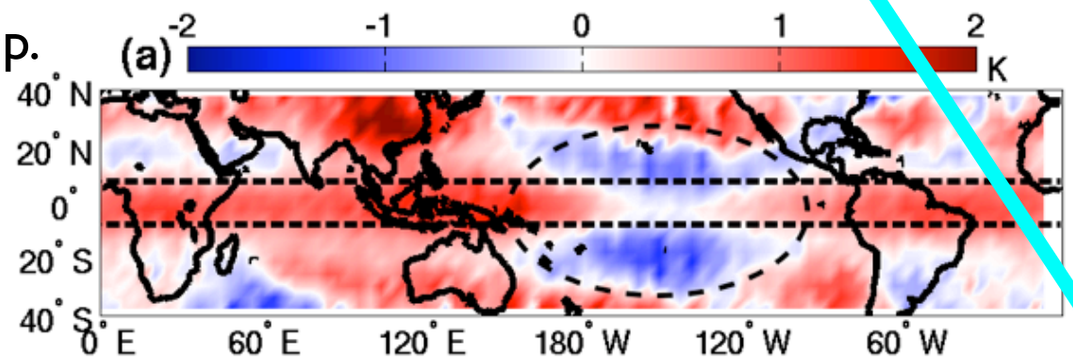
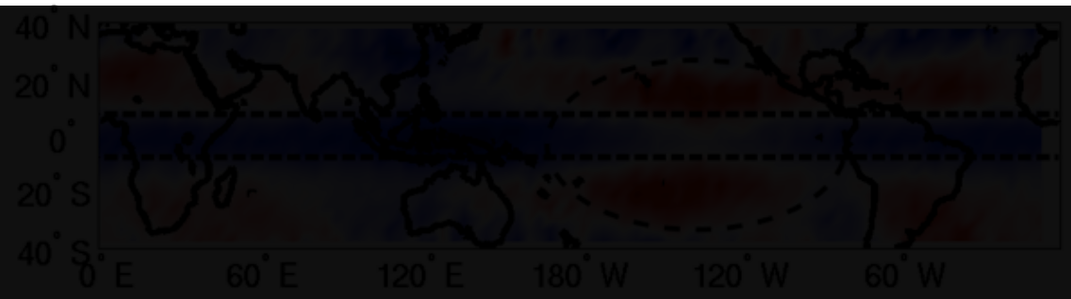
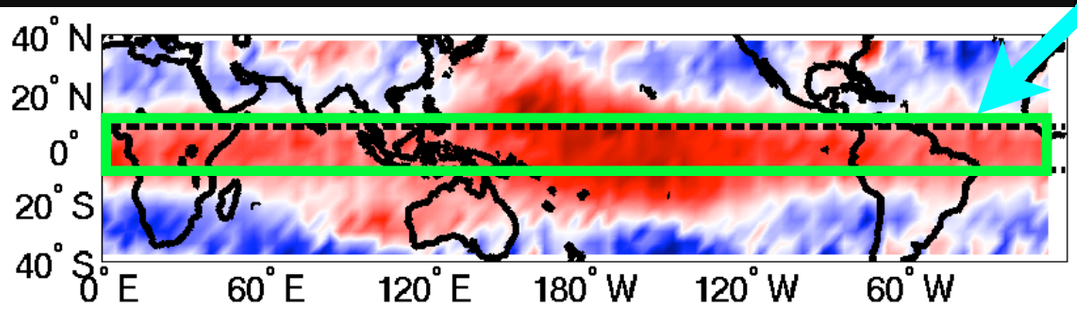
E01 (E+Q+)

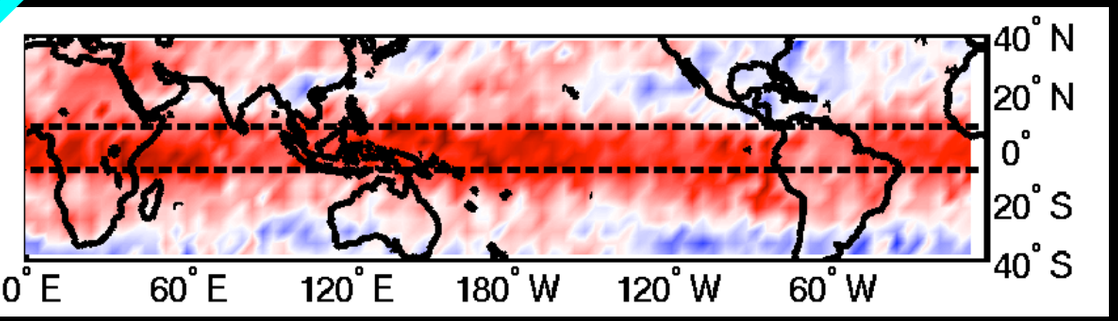


L01 (E-Q-)

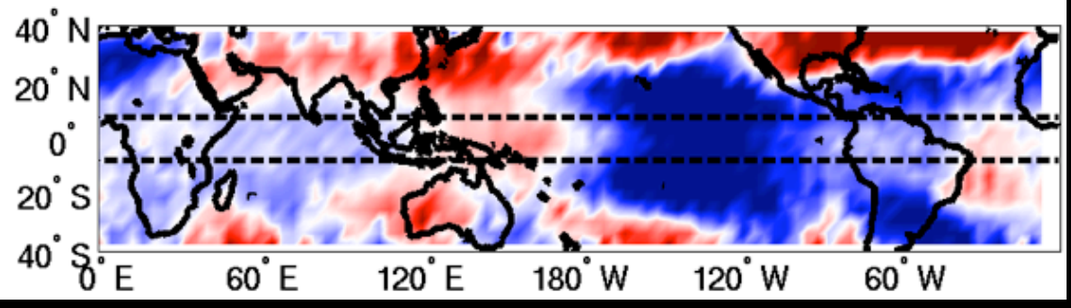


For ONI ~ 0 (~Fall of 2008), and +QBOI we see the zonal symmetry of the QBO





E02 (E+Q*)



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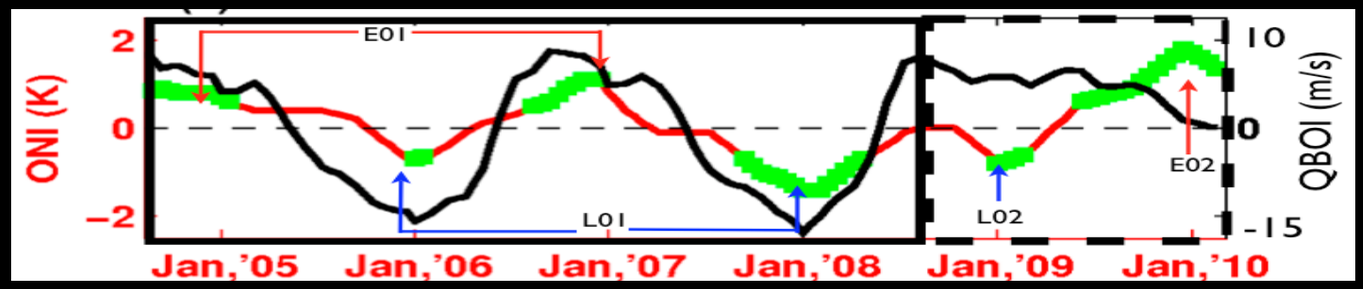

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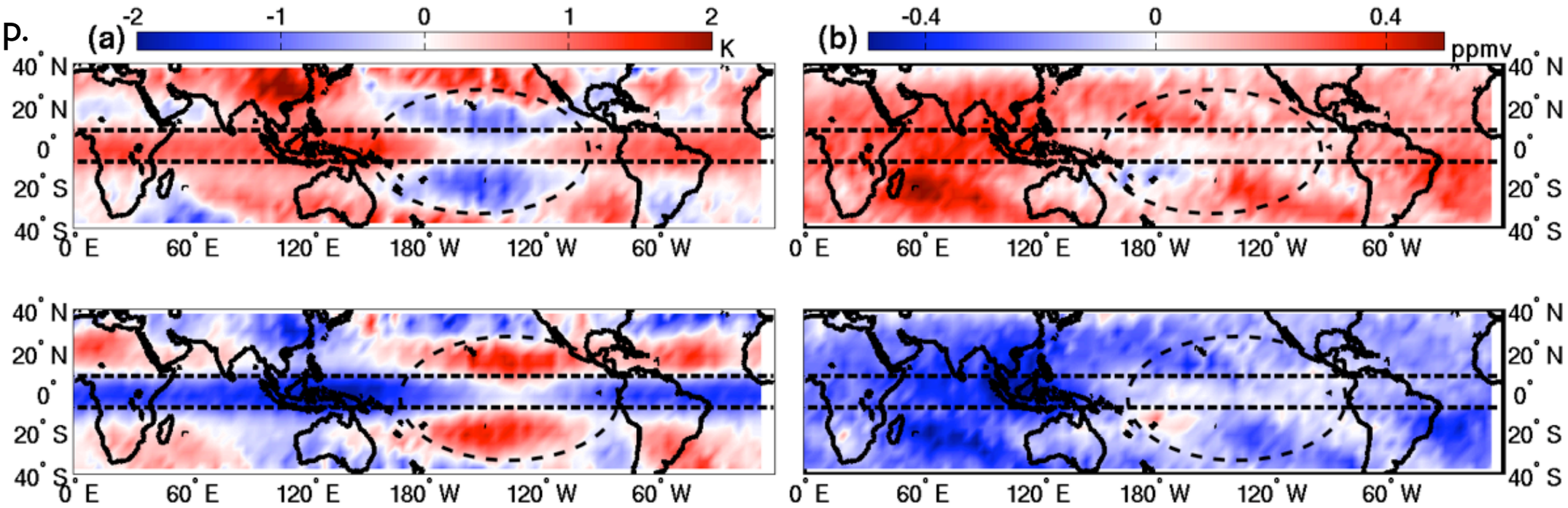
ΔT (100 hPa)

Δq (100 hPa)

DJF Comp.

E01 (E+Q+)

L01 (E-Q-)



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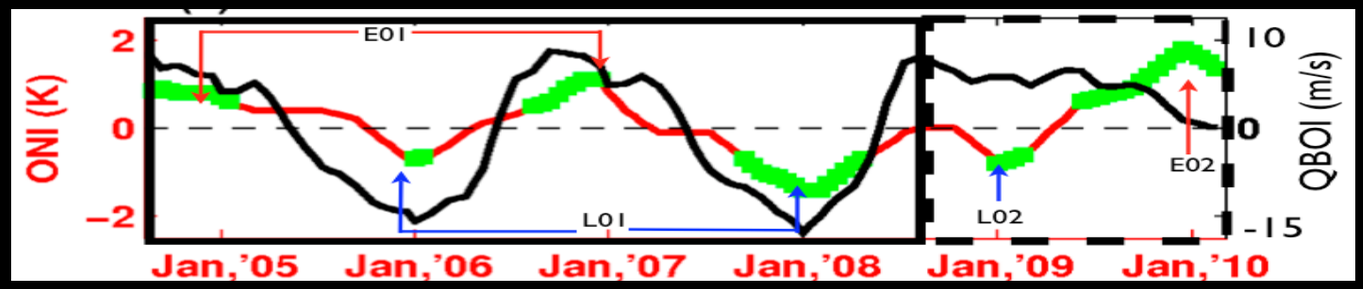

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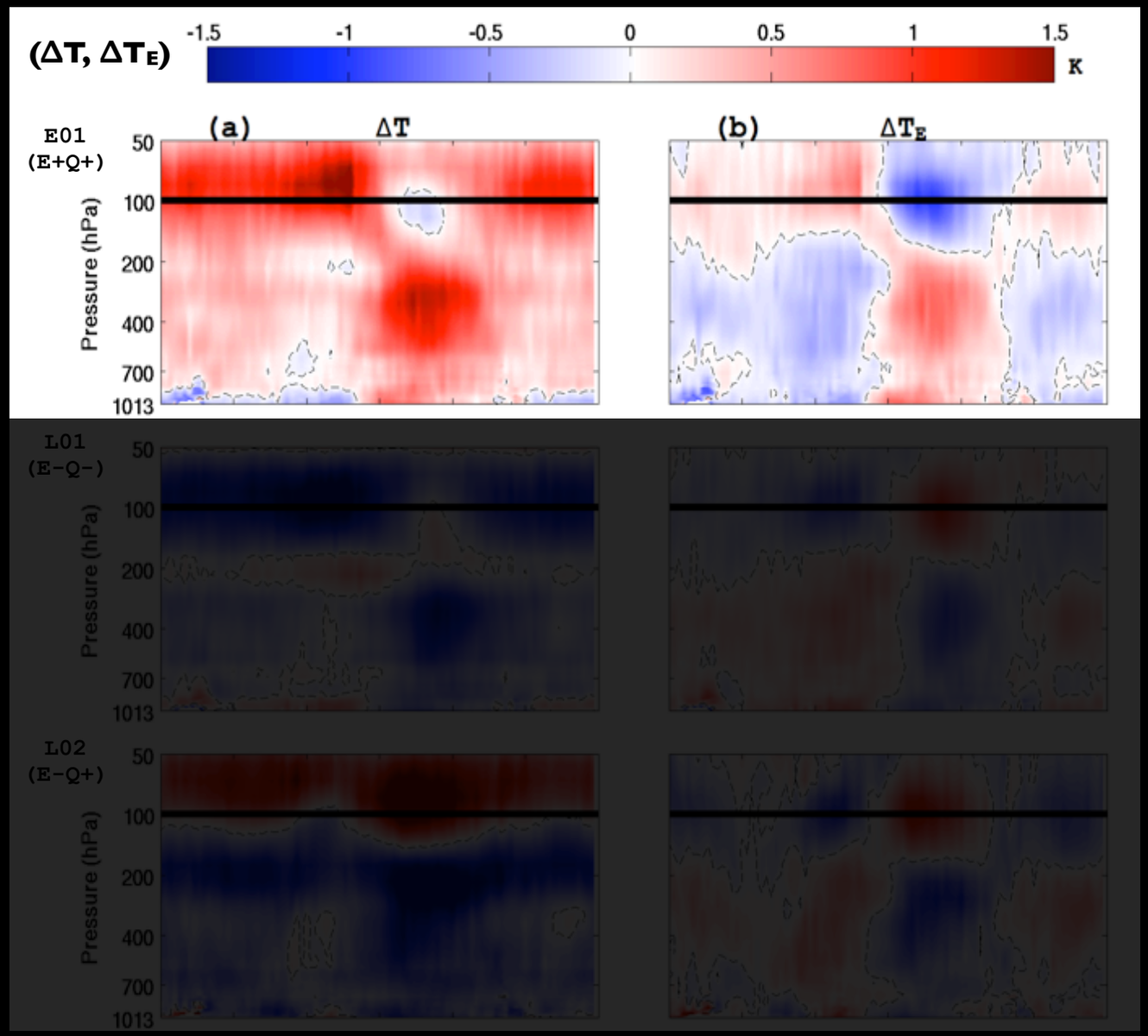
Vertical and Zonal Structure of ΔT and Δq



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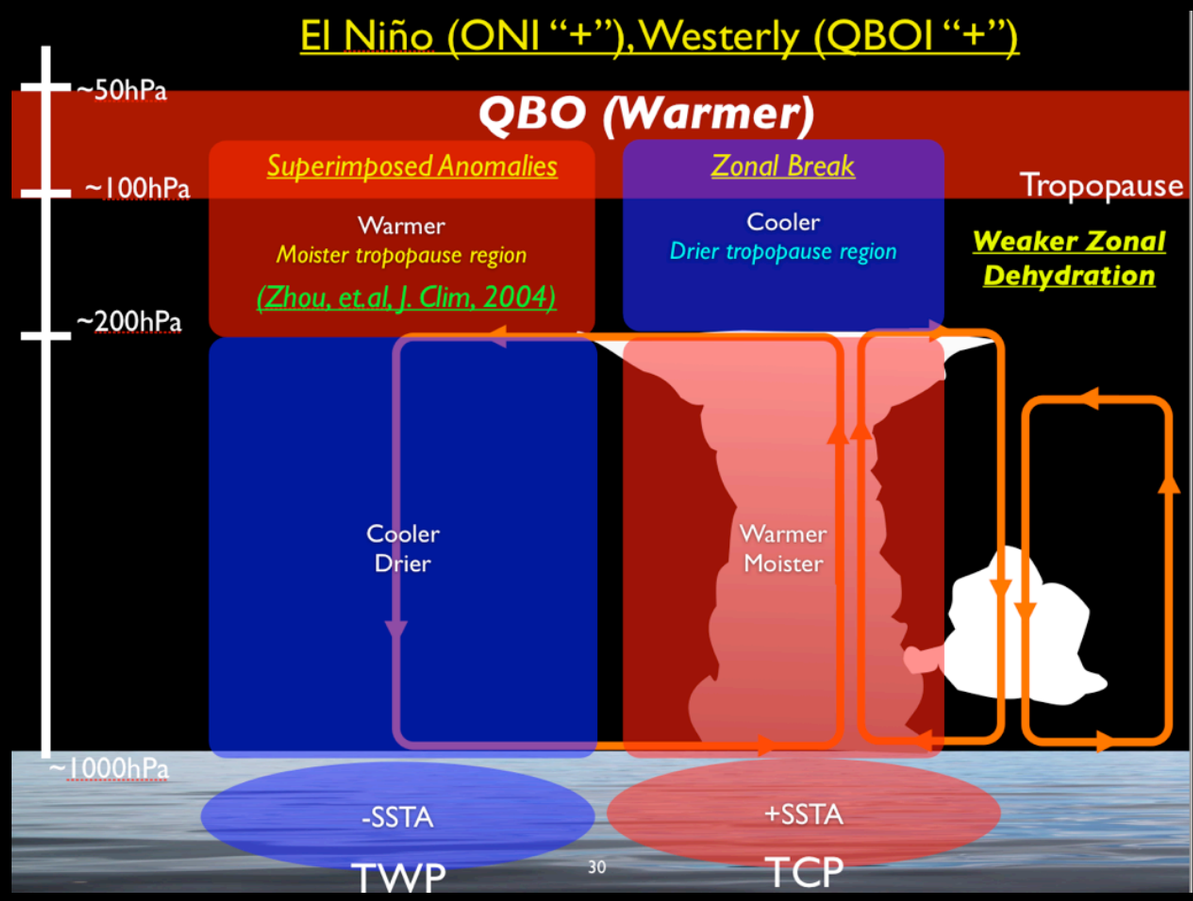
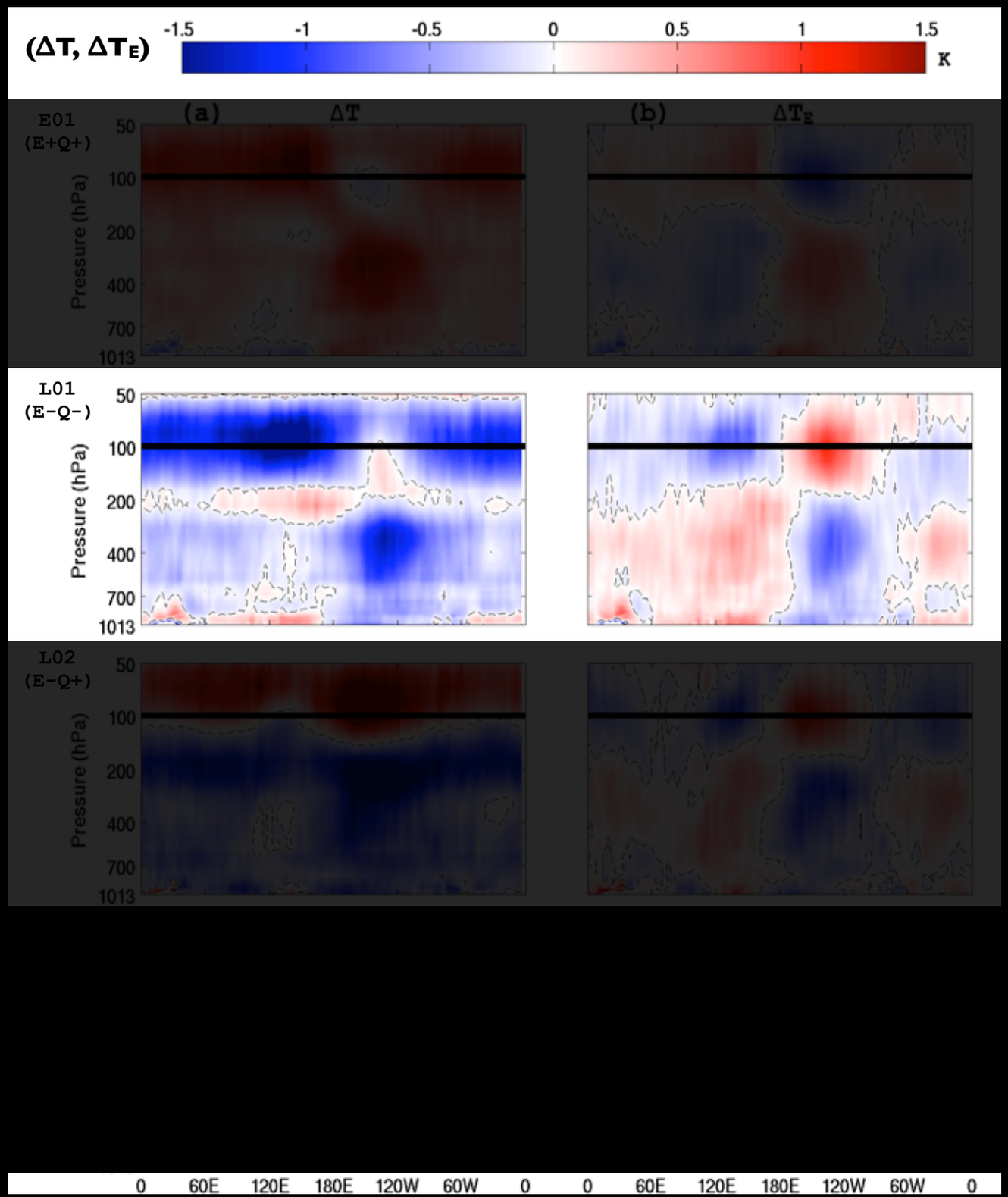
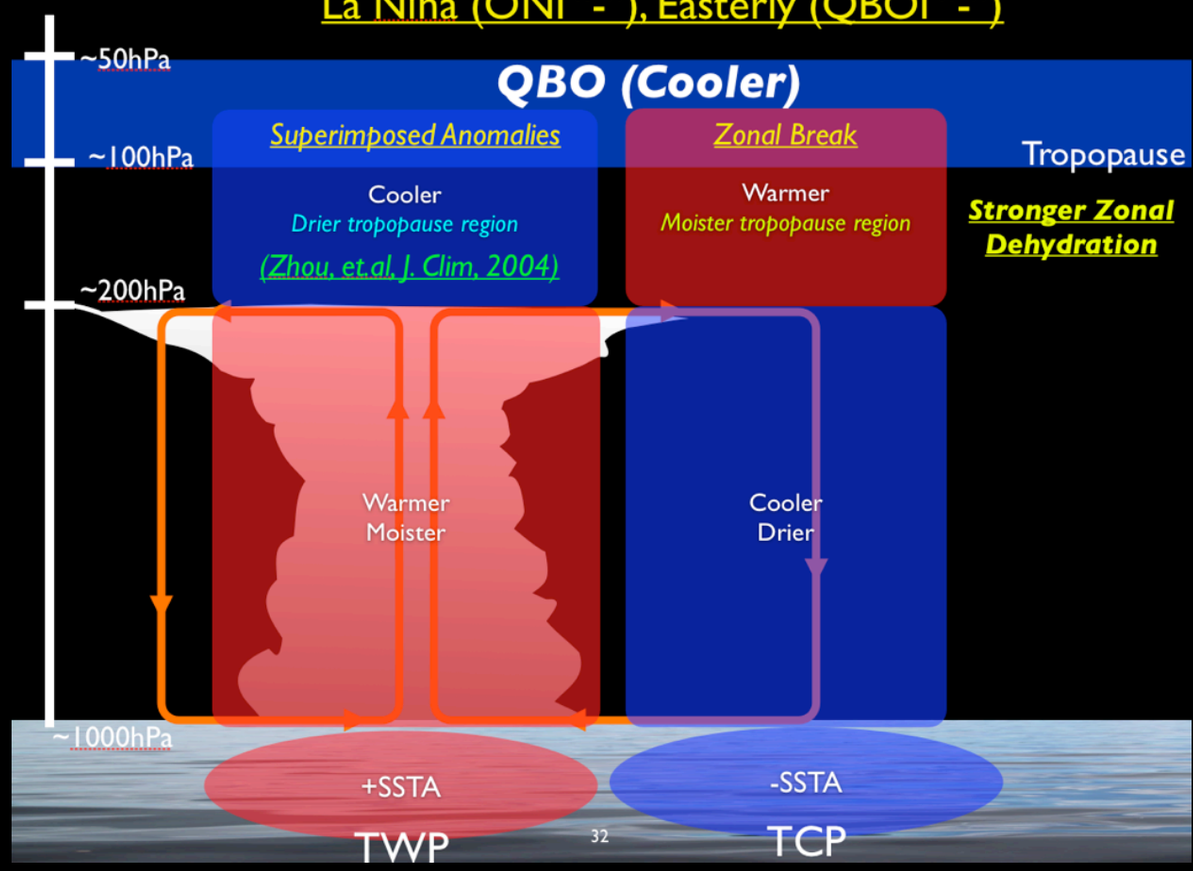


- Zonal break in QBO signal is due to ENSO induces changes in convection
- ΔT_E shows quadrupole structure between TCP and TWP.

Vertical and Zonal Structure of ΔT and Δq





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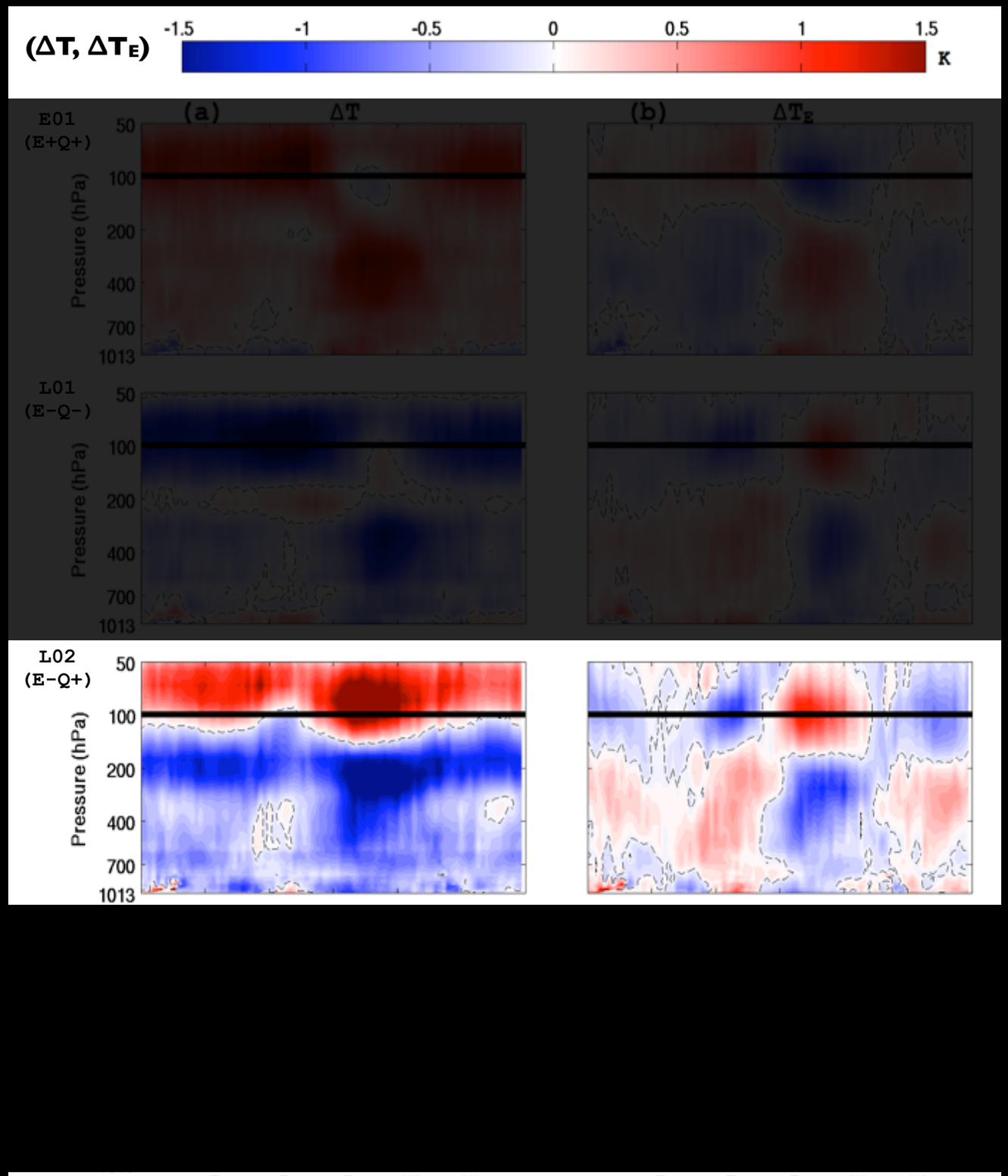

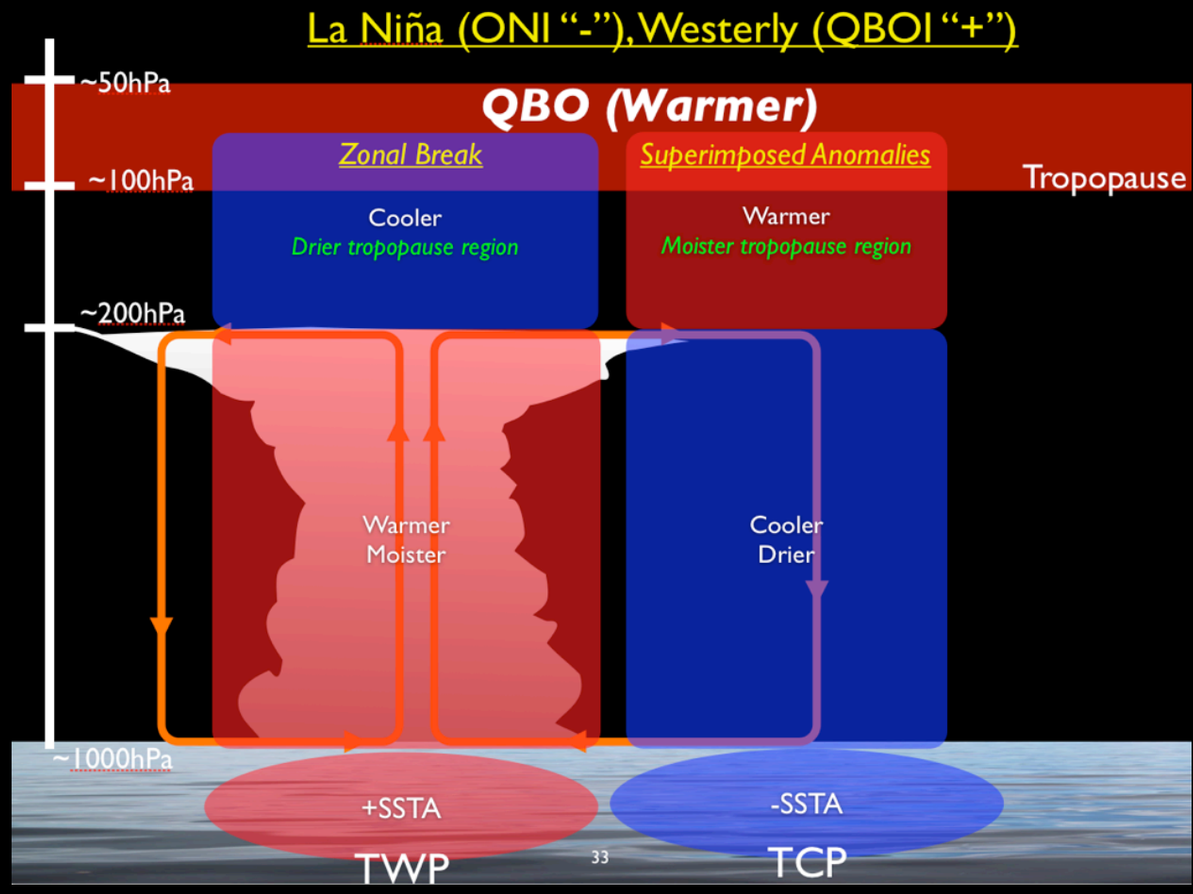

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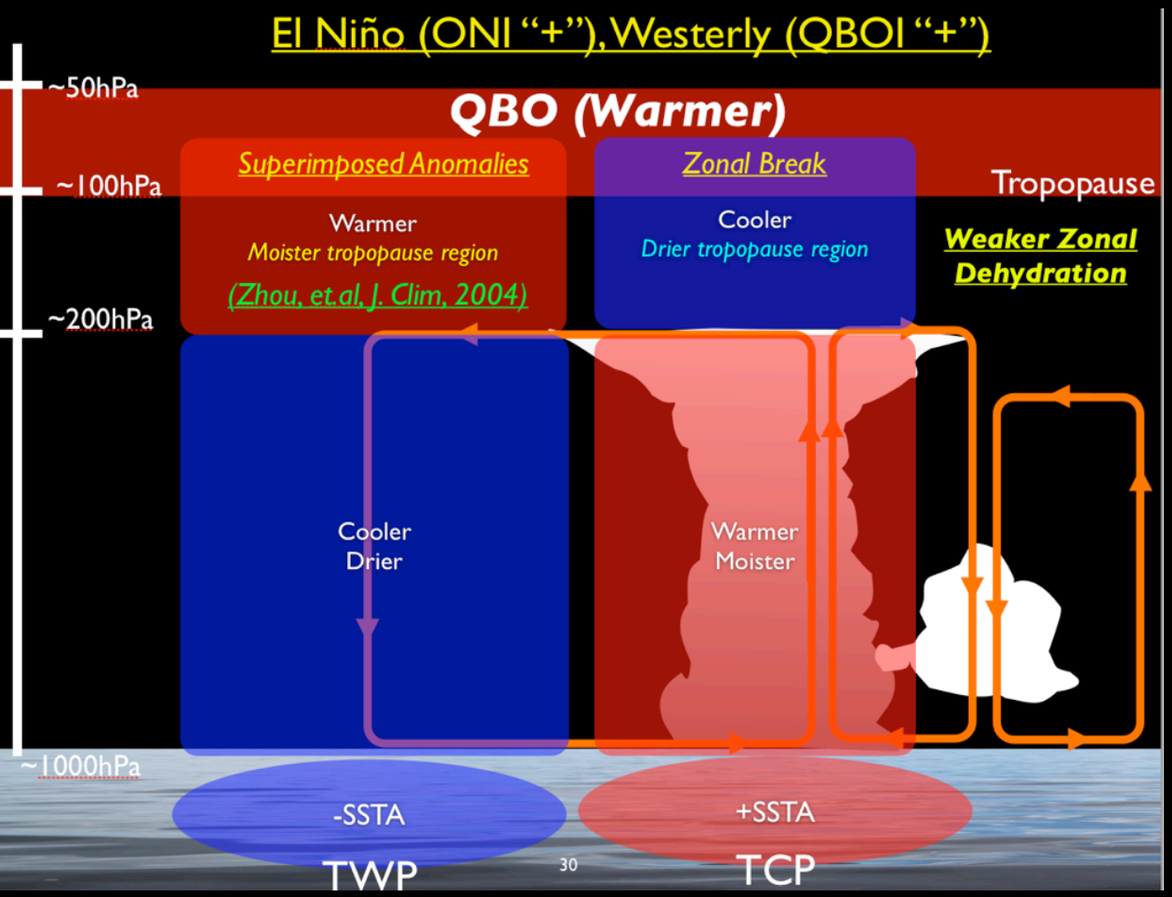
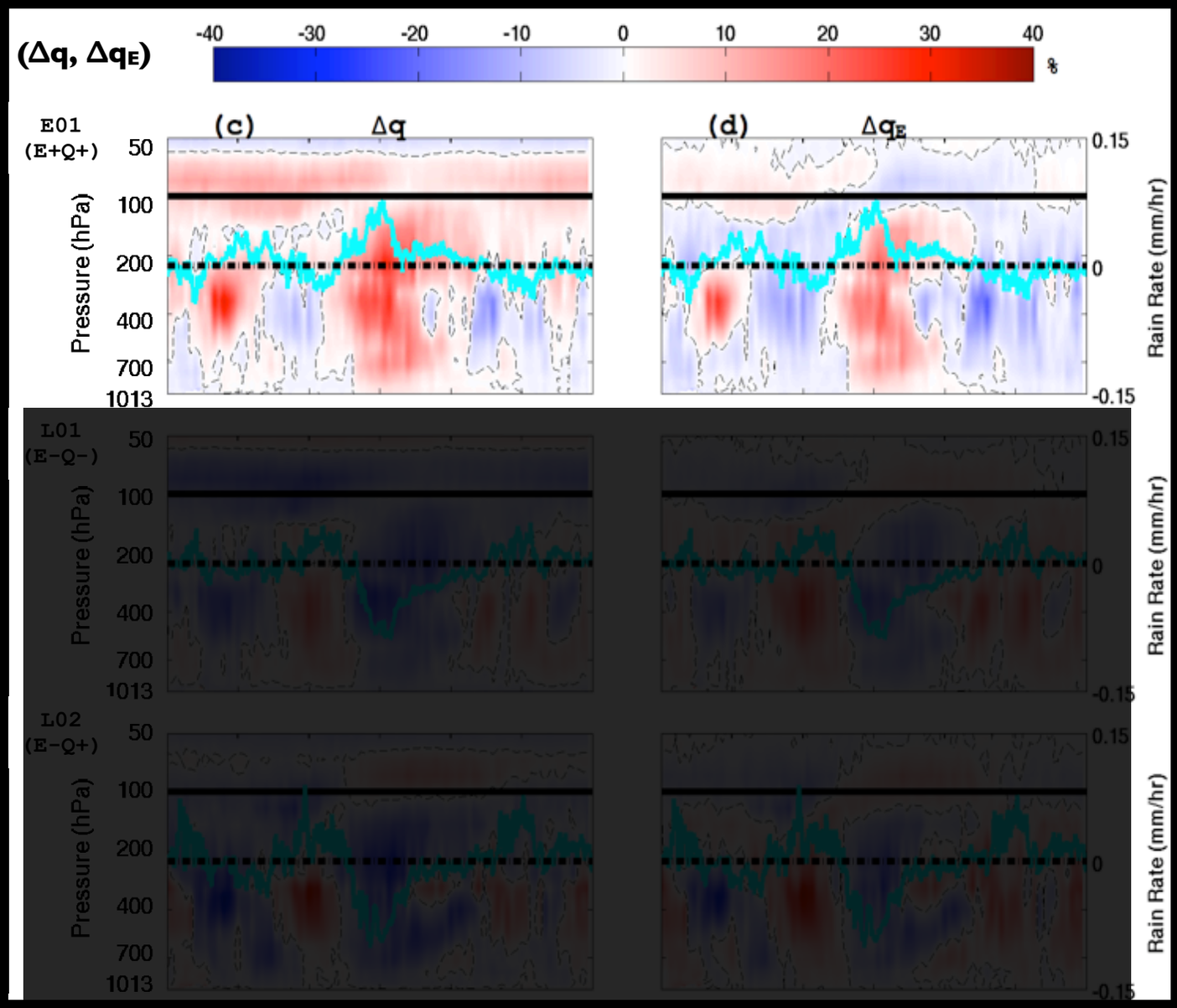
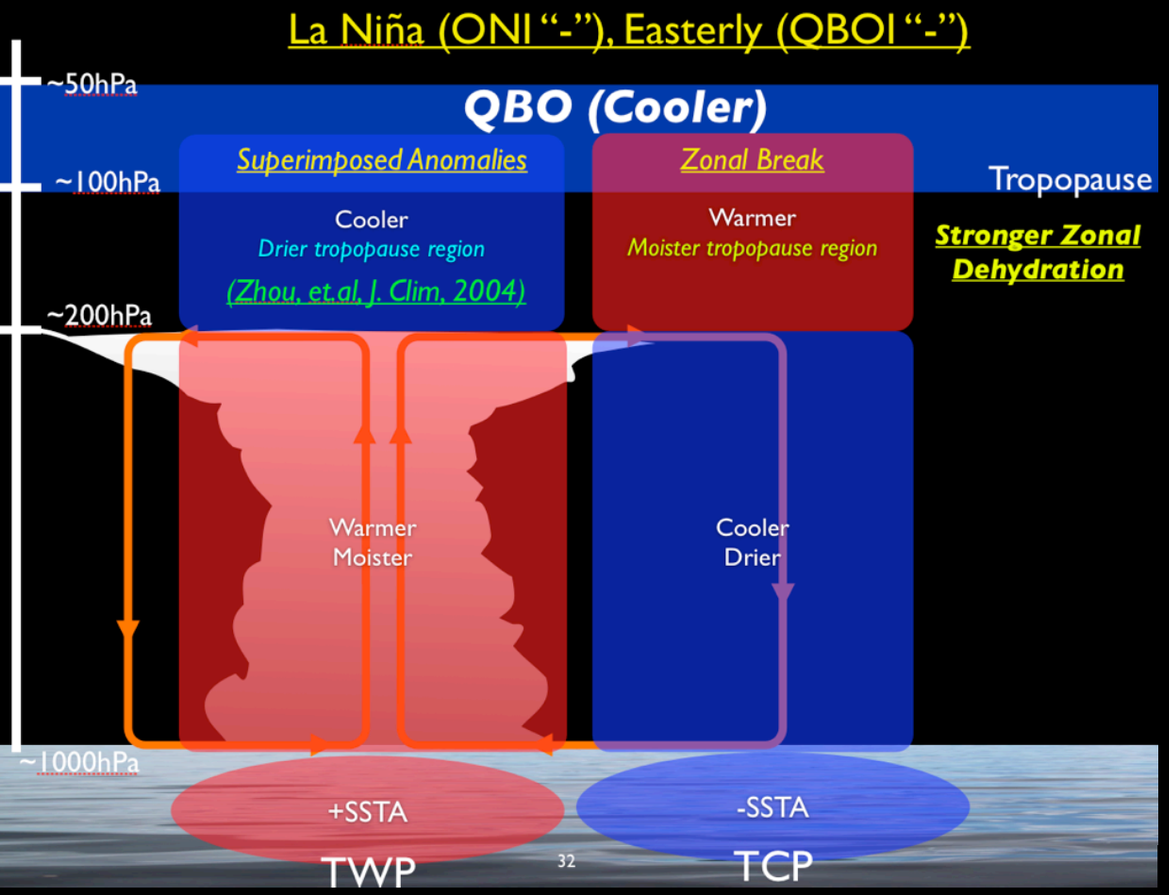




- Moisture and rain rate (TRMM) anomalies track each other
- Δq_E shows moisture also has quadrupole feature like ΔT_E but with different vertical extent

Liang, et.al, JGR (2010), Manuscript in review

Vertical and Zonal Structure of ΔT and Δq



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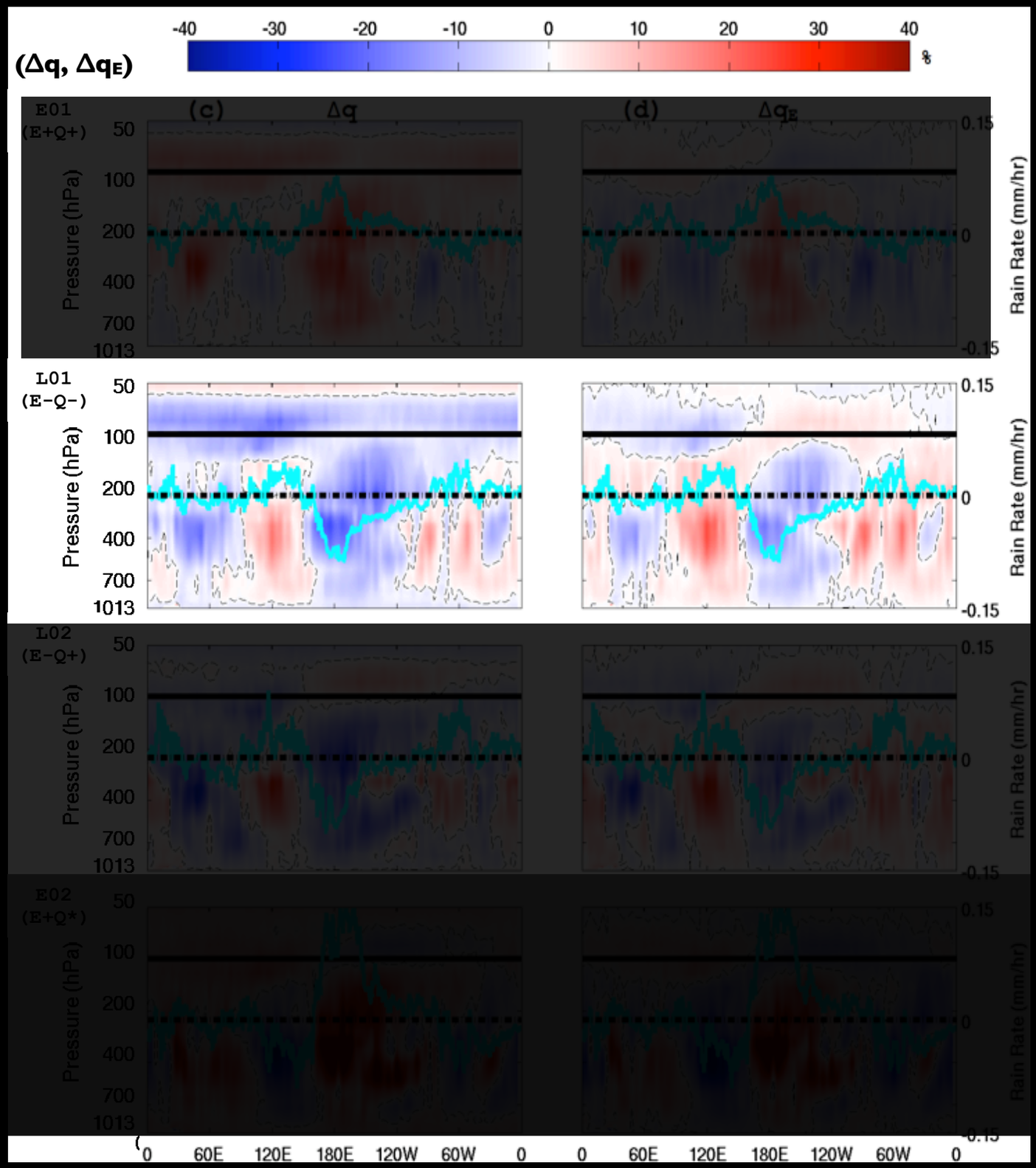

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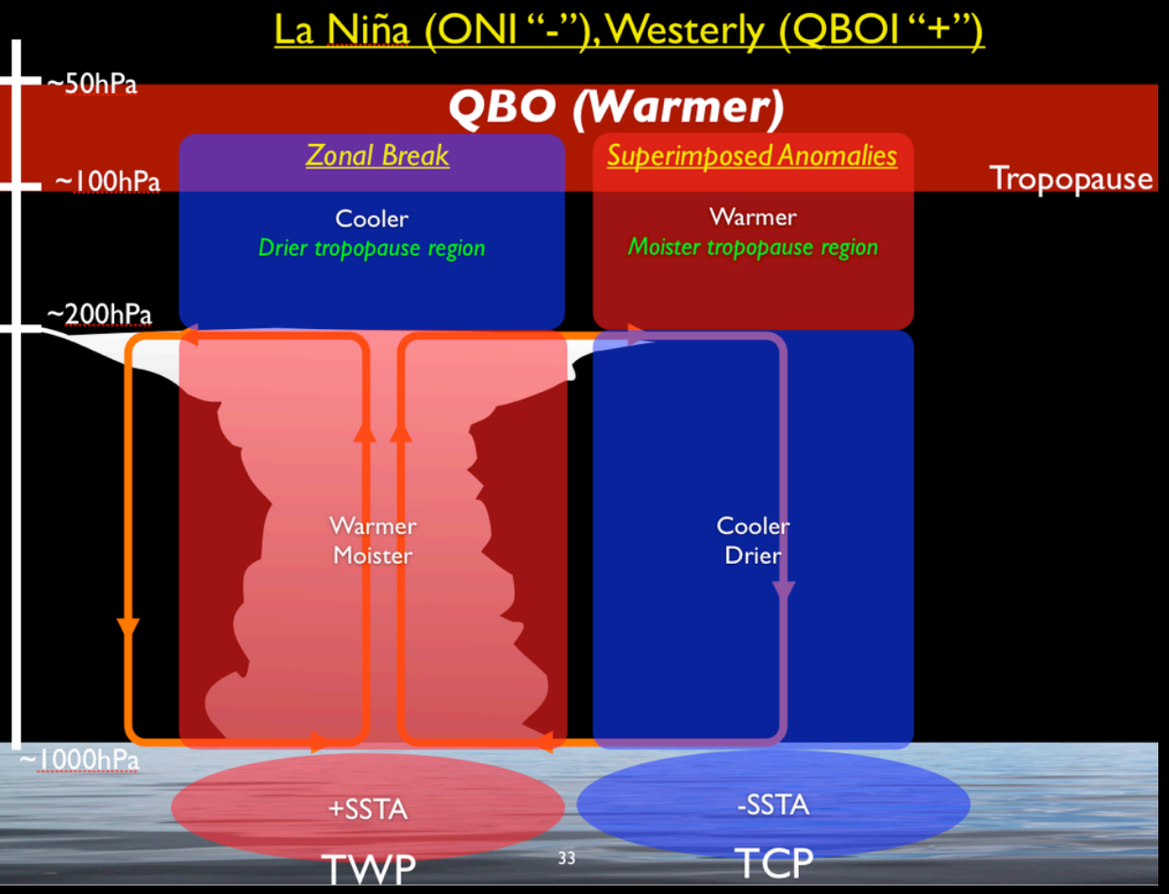

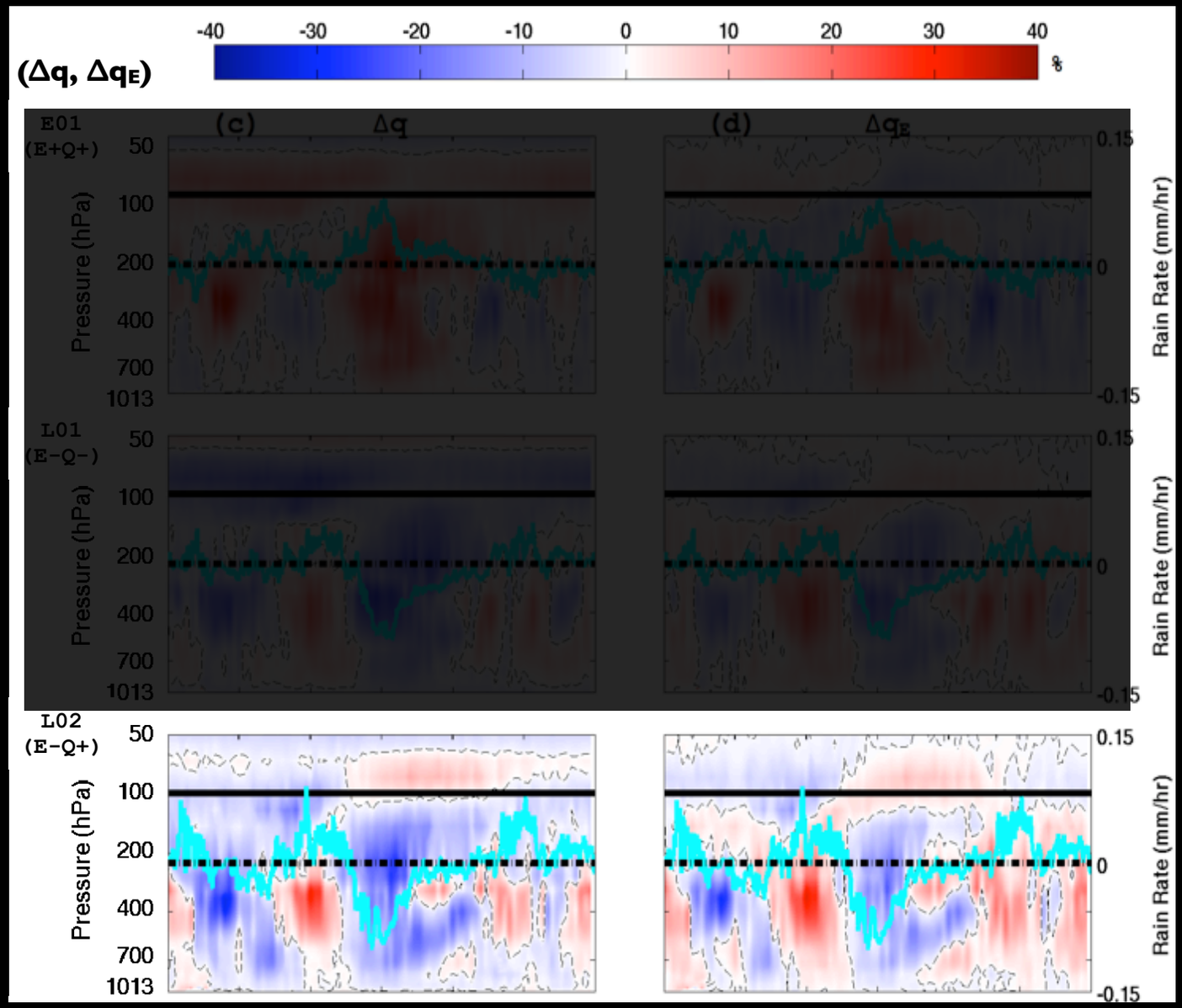

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Conclusion

- TTL T and H_2O anomalies show a location dependent zonal break depending on the relative phase of the ENSO and QBO.
- Changes in Walker Circulation, i.e. deep convection, is one of the main mechanisms
- Evidence of joint ENSO and QBO impact on zonal water vapor distribution; TCP might play a role.
- ***Multi-sensor A-Train measurements allows us to characterize tropical UTLS T and H_2O structure***
- ***Next step: Integrate CloudSat and CALIPSO measurements to connect interannual changes in T and H_2O to cloudiness***

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Thank You!!!

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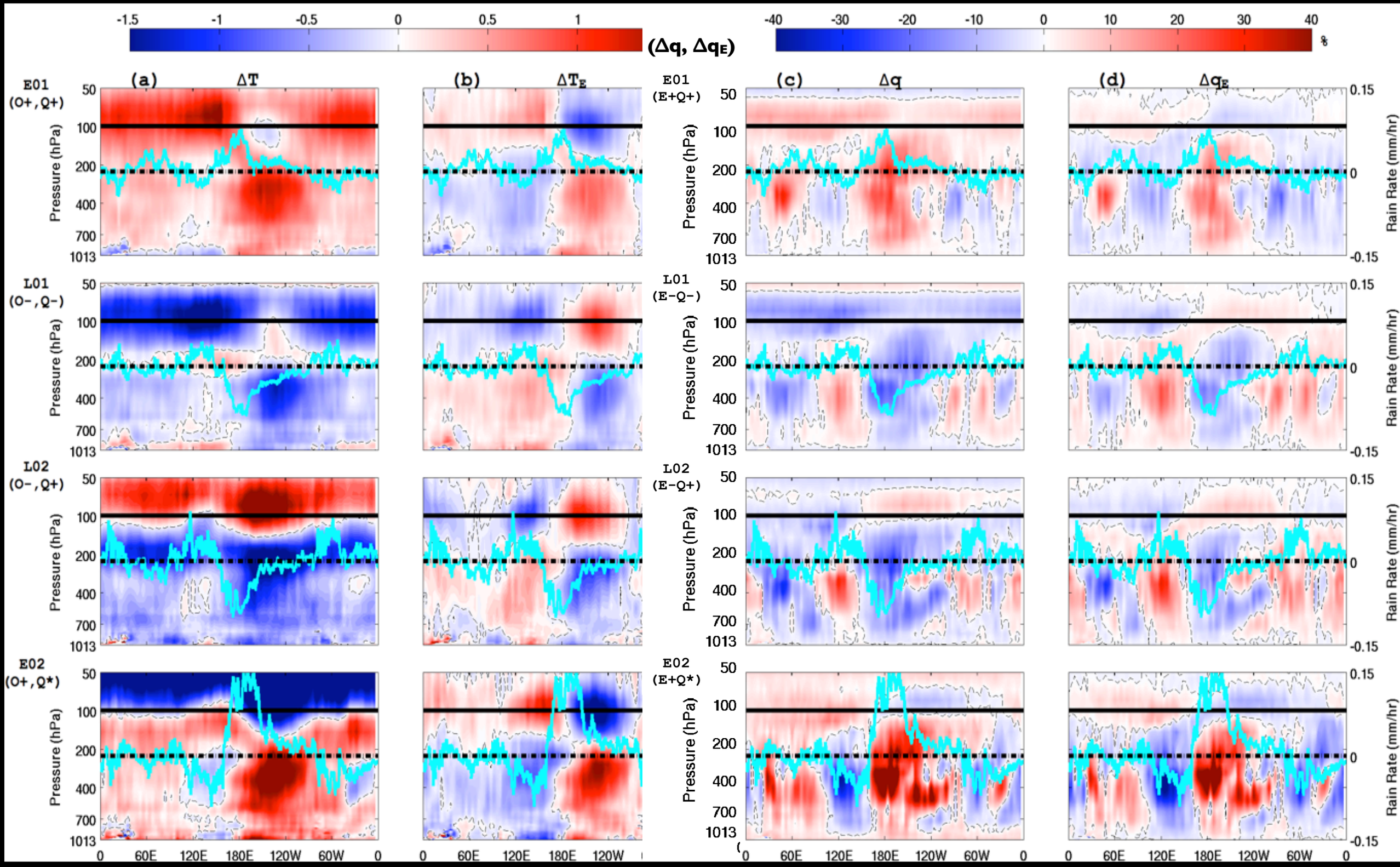

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